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ABSTRACT

This guide is intended to provide the teacher of secondary school physical science classes with a source of information about recent applications, discoveries, and innovations in aerospace. Each section of the guide is subdivided into parts in which objectives are listed, background information for the use of the teacher and/or the student is presented, and activities are suggested. Where problems involving numerical calculation are provided, answers are given. Sections on astronomy, earth science, units of measurement, heat and heat engines, sound and light, electricity, atomic and nuclear physics, and chemistry are included. Each section has a number of subsections, each dealing with a single topic. At the end of each section is a list of resource materials including books, films and other media. The resource lists are collected into a general bibliography, and a list of distributors and publishers is appended. [Not available in hardcopy due to marginal legibility of original document.] This work was prepared under an ESEA Title III contract. (Author/AL)

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RELATING AEROSPACE
TO PHYSICAL SCIENCE

Grades 7-12

(To be revised)

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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Lincoln Aerospace Curriculum Development Project
Lincoln Public Schools
Lincoln, Nebraska

1968-69

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RELATING AEROSPACE
TO PHYSICAL SCIENCE

Grades 7-12

(To be revised)

Compiled and Edited by

Dr. Mary H. Williams
Mrs. Jean Rademacher

Lincoln Aerospace Curriculum Development Project
Lincoln Public Schools
Lincoln, Nebraska

1968-69

September, 1968

The material in this book was developed as part of the Lincoln Aerospace Curriculum Development Project, funded under Title III of the Elementary-Secondary Education Act of 1965.

The units were produced during the summer of 1968 by teachers in the secondary schools, in an eight-week workshop-seminar conducted by the Lincoln Public Schools in cooperation with the University of Nebraska. Professor Frank E. Sorenson, Chairman of the Department of Educational Services and Professor of Secondary Education, University of Nebraska, was the general chairman of the institute. He was assisted by Dr. Jean McGrew, Miss Evelyn Sedivy, Mr. Larry Barnes, and Mr. Jerry Beckmann.

Cooperating with the Lincoln Public Schools in this project designed to help bring the curriculum up-to-date are:

The Catholic Diocese Schools, Lincoln, Nebraska
Grand Island Public Schools, Grand Island, Nebraska
Hastings Public Schools, Hastings, Nebraska
Kearney Public Schools, Kearney, Nebraska
Millard Public Schools, Millard, Nebraska
Westside Community Schools, Omaha, Nebraska

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During the summer of 1967, under the leadership of Dr. Milton Horowitz, Queens College, New York, a group of junior high school teachers began work on aerospace-oriented teaching materials for use in science classes. In the summer of 1968, in an eight-week workshop coordinated by Dr. Jean McGrew, University of Nebraska, teachers from junior high schools and senior high schools continued this endeavor.

It is hoped that these aerospace-related concepts will enrich the physical science programs at the secondary level, and will increase the students' awareness of advances which are being made in air and space technology.

The following teachers contributed to this book of aerospace-related concepts in physical science:

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INTRODUCTION

Along with the technological advances which have resulted from the space program, great advances have been made in all of the physical sciences. To keep instruction in these sciences as up to date as possible involves constant striving to assimilate the latest information into the curricula.

The purpose of this guide is to provide the teacher of physical science classes, at the secondary school level, with a source of information about recent applications, discoveries, and innovations in aerospace which are related to the physical science areas. Each section of the guide is subdivided into parts in which objectives are listed, background information for the use of the teacher and/or the student is presented and activities are suggested. At the end of each section is a list of resource materials including books, films, AND OTHER MEDIA.

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ASTRONOMY

Space science has had a tremendous effect upon the science of astronomy. Data collected by rockets and satellites have added greatly to the store of information about the universe. The orbiting geophysical observatory (OGO), to explore space near the earth; the orbiting solar observatory (OSO), to collect data about the sun; and the orbiting astronomical observatory (OAO), to make observations of the universe without the interference of the earth's atmosphere, are the standard satellites for collecting astronomical data.

The Russian Lunik series and the United States' lunar spacecraft explorers -- the Ranger, Surveyor, and Lunar Orbiter -- have collected extensive data about the moon. In addition, exploration of the moon through the manned space programs -- Mercury, Gemini, and Apollo -- has given scientists more accurate and more complete information about the moon and its environment. Additional information about the planets of the solar system has been collected by the Mariner planetary probes which have been flown by the planets Venus and Mars.

Earth's Moon. 3

Mars and Venus. 7

Sun 9

Stars 11

Resource Materials. 13

EARTH'S MOON

Objective

To be able to describe the purposes and the results of the following lunar exploration programs: Ranger, Surveyor, Lunar Orbiter, U.S.S.R. Lunik, Mercury, Gemini, and Apollo.

Background Information

Only when man lands on the moon, and perhaps not even then, will the questions scientists have about the moon, its origin, its surface, and its internal structure, be answered. The Ranger, Surveyor, and Lunar Orbiter programs have all been planned and executed to gather information about the moon for the purpose of landing a man on the moon. Experiments conducted in the Mercury, Gemini, and Apollo programs have contributed to the development of the technology needed to land a man on the moon. The successful check out of the Lunar Module in the Apollo 9 flight means that on the Apollo 11 flight an astronaut will be placed on the moon.

NASA's Project Ranger (August 23, 1961 - March 21, 1965), planned to take close-up photographs of the surface of the moon, was unsuccessful until Rangers VII, VIII, and IX were launched. From these three successful launches 17,255 close-up pictures of the moon were obtained. Ranger VII landed near the northwest corner of Mare Nubium (Sea of Clouds); Ranger VIII, in the western part of Mare Tranquillitatis (Sea of Tranquility); Ranger IX, in the Crater Alphonsus. A study of the photographs received has shown: (1) mare (plains) areas are more level than anticipated and smooth enough for safe landing; (2) there is considerable evidence of erosion on the moon; (3) Mare Nubium, Mare Tranquilitatis and the floor of Crater Alphonsus are dotted with small craters; (4) Crater Alphonsus has a mountain peak at the center, suggesting possible volcanic activity; (5) small "halo" craters, whose "halo" appears to be a dark material deposited on the surface, are found within the Crater Alphonsus; (6) long rilles, some of which are chains of small craters, appear in the Mare Tranquillitatis and the Crater Alphonsus, (7) several "dimple" craters, which suggest that soft material of the moon's surface may be draining into subterranean caverns, have been photographed, and (8) mountain peaks and crater rims are more gently rounded than anticipated.

The purpose of the Surveyor program was to accomplish soft landings on the moon. Surveyor I was launched May 30, 1966, and, about 63 1/2 hours later, made a soft landing in the Oceanus Procellarum (Ocean of Storms) area of the moon where it made numerous scientific tests and took many pictures of the moon's surface. Of the six Surveyor spacecraft that followed Surveyor I, two were unsuccessful in landing on the moon; the other four collected much valuable data.

The last Surveyor, Surveyor VI, was launched January 7, 1968. Preliminary analyses of the data collected show that (1) man will be able to walk on the surface of the moon, leaving only shallow footprints; (2) the surface of the Lunar maria is covered with extremely fine particles and strewn with many blocks and larger fragments of material; (3) the material below the moon's surface is of a darker color than the surface soil; (4) there is much evidence of erosion; perhaps from volcanic action or impacts of meteorites; (5) surface soil of the lunar maria most nearly resembles basalt which, on Earth, has been formed by volcanic action; (6) material on lunar highlands is similar to that in the plains areas, but contains less iron; (7) highlands have more large rocks, fewer craters, and a thinner covering of fine particles than the plains areas.

NASA's Lunar Orbiter program, beginning with Lunar Orbiter I, launched August 10, 1966, and ending with Lunar Orbiter 5 launched August 1, 1967, consisted of five flights to orbit the moon. The entire lunar surface was photographed for mapping purposes, and, in addition, photographs were taken to provide necessary detailed information about possible landing sites for Apollo flights. The Lunar Orbiters also provided information about micrometeoroid density, radiation flux, and the moon's gravitational field.

Project Mercury, the first phase of the program of manned exploration of the moon, was planned to test man's reaction to the environment of space. This project involved 25 space flights each with either an astronaut or an animal as a passenger. Flights made during the program proved that man is capable of enduring the hazards of both suborbital and orbital flight and provided valuable experience and information about operational procedures.

Project Gemini, the second phase of the manned exploration of the moon, was planned to develop operational techniques for rendezvous and docking procedures and to train crews for the third phase, Project Apollo, in which man would actually land on the moon's surface.

The first nine Apollo flights have been utilized to perfect equipment and operational procedures for the Apollo 11 flight which is to place a man on the moon. The successful performance of the Lunar Module on the Apollo 9 flight will be followed by the Apollo 10 flight in which the spacecraft will orbit the moon, but not land. Astronomers are anxious to receive the firsthand information which only a man on the moon will be able to collect.

U.S.S.R. space flights to the moon began January 2, 1959, with the flight of Luna 1 which passed the moon at a distance of over 5,000 kilometers and continued on to orbit the sun. Data sent back by Luna 2, launched September 12, 1959, indicated that the moon has no magnetic field and no radiation belts. Luna 3 (October 4, 1959) photographed the dark side of the moon for the first time. Luna 9 (January 31, 1966) made the first soft landing on the moon.

Lunas 10, 11, and 12 were placed in lunar orbit to photograph the moon's surface. Luna 13 landed on the moon and returned photographs of the surface as well as soil density data. Luna 14, now in lunar orbit, is collecting data related to the moon's gravitational field, the stability of radio signals, the charged solar particles in the moon's environment, and the relationship between the masses of the earth and the moon.

Activities

1. Test the relative hardness of materials by pushing a soda straw through cotton, marshmallows, rice, coarse gravel, dirt, small rocks and a white potato.

2. Simulate the surface of the moon in order to hypothesize about the origin of the moon's craters.

    a. Simulate the formation of craters by meteor impact. Drop marbles onto dust, sand, and thick mud surfaces.

    b. Simulate the formation of craters by volcanic action. Sprinkle enough plaster of paris into boiling water to make a thick creamy mixture. Continue to heat sufficiently to keep the mixture bubbling slowly until it hardens.

3. Assign research topics such as Project Ranger, the Surveyor program, the Lunar Orbiter program, the U.S.S.R. space program, Project Mercury, Project Gemini, Project Apollo, etc.

4. Demonstrate the way in which a strain gauge might measure the hardness of the moon's surface.

    Materials needed:

    - Postal scale
    - Copper tubing or pipe
    - Soil samples

    Using the postal scale which has been inverted, press the tubing into the surface of each of the soil samples. Record the amount of force needed to make the tubing penetrate the soil.

5. Demonstrate the bounce method of testing the hardness of the lunar surface.

    Materials needed:

    - Glass or plastic tubing, 1 foot long, 1 inch in diameter
    - Marbles or steel balls, less than 1 inch in diameter
    - Ruler
    - Soil samples

With the tubing standing upon the surface to be tested, drop a marble down the tube. Measure the height to which the marble rebounds. The ratio between the original drop distance and the rebound distance could be used as an index of surface hardness.

MARS AND VENUS

Objective

To be able to describe the purposes and results of the Mariner and Voyager programs to explore the planets of the solar system.

Background Information

Although long range plans include projects for the study of all the planets in the solar system, the space program so far has been involved primarily in exploration of Venus and Mars. Much new information about each of these two planets has been collected as a result of the Mariner flybys.

On December 14, 1962, Mariner II flew past Venus at a distance of 21,648 miles from its surface. The following information about Venus was collected by the spacecraft: (1) Surface temperature may be as hot as 800° Fahrenheit. (2) Dense clouds cover the planet, starting at 45 miles above the surface. Temperature at the cloud base is about 200° F; at the middle level, -30° F; at the upper level, -60° F. (3) Venusian clouds do not consist of water vapor, and no carbon dioxide was found above the clouds. (4) No magnetic field or radiation belts were detected. (5) Micrometeorite measurements indicated that there are relatively few micrometeorites near Venus as compared to the number in space near Earth.

Radar reflections have indicated that the surface of Venus is a sand or dirt-like material and that Venus seems to rotate backwards as compared to Earth; that is, east to west. A spot in the clouds that is 20° F cooler than the surrounding clouds was detected. These data led to the speculation that Venus, where the sun rises in the west and sets in the east, may be a hot, desert with searing winds whipping up sand storms. The daytime twilight and the nighttime glow caused by the heavy cloud cover lasts for about 123 Earth days each.

Mariner V which flew by Venus on October 19, 1967, provided confirmation for much of the data received from Mariner II and additional information which has enabled scientists to conclude: (1) The atmosphere of Venus is so dense that light and radio waves may be reflected around the planet. (2) Carbon dioxide may be a major constituent of the atmosphere (Later analysis of information leads to the conclusion that CO_2 is only about 10 per cent of the atmosphere, and it is assumed that nitrogen is the major component.) (3) Venus' exosphere or corona is primarily hydrogen with a temperature of about 700° F, a much lower temperature than in the earth's hydrogen corona. (4) No free oxygen was found in the exosphere. (5) There is an ionosphere whose daytime electron density is 100 to 1000th of the nighttime density. (6) No magnetic field was detected.

Radar studies indicated that Venus rotates once every 243-247 days, but its atmosphere circles the planet about every five Earth days which would indicate that the surface is lashed by strong winds. (7) Venus is surrounded by a shock wave similar to that around Earth where the solar wind meets the earth's magnetic field. (8) Data collected established with great accuracy that the mass of Venus is 0.815 of the earth's mass.

Mariner IV, flying as close as 6118 miles from Mars, took 21 historic photographs of the Martian surface which appears pitted with craters like the impact craters of the moon and the earth. No mountain chains, valleys, ocean basins, or ancient rivers and lakes were shown. The surface pressure of the Martian atmosphere was measured at lower than 10 millibars, compared to the sea level measurement of approximately 1000 millibars on Earth. The Martian ionosphere was found to be capable of reflecting radio waves as high as 3000 kilocycles making it possible to maintain radio communication between points on the planet's surface. No Martian magnetic field or radiation belts were detected. Contrary to what scientists had anticipated, there was no significant increase in micrometeroids in the vicinity of Mars.

Mariner VI, launched February, 1969, will, it is hoped, take even better pictures of the Martian landscape as the spacecraft flies by within 2000 miles of the planet's surface. Mariner VII, identical to Mariner VI, was launched March 27, 1969, to flyby the south polar region of Mars. Included on these spacecraft, in addition to the television cameras, are instruments to analyze gases in the Martian atmosphere and to record atmospheric temperature and pressure. The temperature of the Martian surface will be measured also by infrared radiometers.

The Voyager program is planned as an exploration of nearby planets by a combination of orbiting spacecraft and landing craft. The major purpose of the landing craft will be to locate any evidence of extraterrestrial life. Though much research and development has already gone into the Voyager program, there is much yet to be done before Voyager I is launched.

Activity

Have interested students research the following topics and report their findings orally or in written form.

Mariner spacecraft program
Voyager spacecraft program

SUN

Objective

To be able to describe the results of data collected about the sun by Pioneer space probes, Orbiting Solar Observatories, Mariner space probes, and Explorer satellities.

Background Information

Information about the sun has been collected by Pioneer interplanetary probes, the Orbiting Solar Observatories, Mariner space probes, and some of the Explorer satellites. Pioneer IV data indicated that the solar wind contains only 50 to 150 ions of hydrogen, helium and other elements per cubic inch of space. This extremely thin solar wind is considered an extension of the sun's corona. The temperature of individual solar wind particles is about one million degrees Fahrenheit. The number of solar cosmic ray particles is small, a ratio of one to one billion when compared to the number of solar wind particles. The maximum velocity of the solar wind was found by Pioneer VI instruments to be nearly 1,700,000 miles per hour. As the particles in the solar wind leave the sun they draw out the sun's magnetic field to form interplanetary magnetic fields. Pioneer VI also collected data which showed that the sun's magnetic field is snarled near the sun and that magnetic lines appear to twist about each other away from the sun.

Galactic rays, composed of protons, alpha particles, nuclei of atoms heavier than hydrogen or helium, and electrons, have energies which range in the millions, billions, and trillions of electronvolts, much higher than energies of solar wind particles which range in the hundreds and thousands of electronvolts. The Orbiting Solar Observatories (OSO) are sun-stabilized platforms from which solar experiments may be conducted. OSO 1, launched in March 1962, collected data which indicated that (1) in the extreme ultraviolet range, changes in the solar corona indicate active areas on the sun's surface and (2) differences in the temperature of the earth's atmosphere at sunrise and sunset were less than had been predicted. OSO 2 data indicated that 80 per cent or more of the visible air glow is produced in a layer about 56 miles above the earth and that day to day variations in its brightness and color are smaller than expected. OSO 3, (1) is gathering data which allows scientists to study the mechanism of energy transportation in the sun's corona, (2) is measuring the absorption of solar ultraviolet radiation by the earth's atmosphere and correlating this data with conditions in the earth's atmosphere, (3) is acting as part of the Solar Flare Warning Network to alert astronauts to streams of high energy particles and (4) is collecting data about the presence of hard gamma rays as a clue to galactic structure and evolution. OSO 4 carries a scanning device that has made it possible to map the sun by X-ray. OSO 5, besides collecting data about the sun in X-ray and ultraviolet light, is monitoring zodiacal light, terrestrial airglow and stellar gamma rays. A total of seven OSO's are to be orbited by the end of 1970.

As Mariner II traveled to Venus, it collected data which indicates that the solar wind is the dominant feature of interplanetary space. This wind of electrically charged protons and electrons is traveling through space at speeds, varying with solar activity and distance from the sun, of 250 to 450 miles per second. Solar cosmic rays spiral through space following magnetic field lines stretching from the sun like streams of water from a rotating water sprinkler.

Explorer VII data on ultraviolet, X-ray, and cosmic ray radiations from the sun indicated that solar flares would be dangerous to an unprotected man in space. Explorers XII, XIV, XV, and XXVI, the Energetic Particle Explorers, were launched to collect data about the natural and artificial radiation belts of the earth and the effect the solar wind has upon these belts. Other Explorer satellites have collected and continue to collect data about solar plasma, solar cosmic rays, and other phenomena of the solar atmosphere.

Activity

Assign research reports on topics such as the OSO, the Mariner program, the Explorer satellites, the Pioneer space probes, the solar wind, etc.

STARS

Objective

To be able to list the limitations of earth-based astronomical instruments, to define types of space astronomy, and to describe the program of the orbiting astronomical observatories, including a list of preliminary data from OAO II.

Background Information

The earth's atmosphere limits astronomical observations in three ways: (1) The atmosphere is opaque to all electromagnetic radiation except that in the 3000 to 10,000 Angstrom wavelengths of the visible spectrum and that in the 3 millimeter to 15 meter wavelengths of the radio spectrum. (2) Skylight in the upper atmosphere and the scattering of sunlight and starlight by the lower atmosphere set minimum limits to the brightness of an observable light source. (3) The relative lack of homogeneity in the atmosphere causes irregular refraction and dispersion of light rays passing through it, thus preventing good resolution of details.

Space astronomy includes ultra-violet astronomy, X-ray astronomy, gamma-ray astronomy, radio astronomy, and infrared astronomy. Astronomers use sounding rockets and satellites to make observations above the earth's atmosphere. Balloons and high-flying aircraft are used to collect data through the relatively less dense upper atmosphere. Major emphasis in space astronomy, at present, is upon the ultraviolet spectrum. Prior to the launching of OAO-A2, most ultraviolet observations were made by Aerobee sounding rockets which have over the past 15 years made observations which total in time only about 200 minutes of actual observation.

X-ray astronomy is a relatively new field of astronomy. The first X-ray sources were discovered by sounding rocket in 1962. Since then many more have been located and so far no suitable theory has been developed which would explain the presence of X-ray sources of the different types and intensities found.

Gamma-ray astronomy is a study of the very short wavelength or very high frequency electromagnetic radiations. Data collected by Explorer XI in 1961 indicated that most of the high energy gamma rays do not originate in the Milky Way Galaxy but come from intergalactic space.

Radio astronomers study electromagnetic radiation at frequencies below 10 megacycles.These wavelengths are absorbed by the earth's ionosphere. Information about this type of radiation may lead to an understanding of the electron density of interstellar space and the interstellar magnetic field.

Early radio astronomy data was collected by sounding rockets and the EGO spacecraft. Radio Astronomer Explorer I (Explorer 38), the world's first space observatory, was launched July 4, 1968, to listen to radio emissions from deep space.

Because of their extremely complicated instrumentation, orbiting astronomical observatories have developed slowly. Plans are for the OAO's to map large portions of the sky--about 60 per cent; and to make intensive studies of specific areas such as the Orion Nebula. Major experiments aboard the OAO's include: (1) the Smithsonian Astrophysical Observatory experiment called Project Celescope which will map the sky in four ultraviolet wavelengths; (2) the University of Wisconsin Space Astronomy Laboratory experiment whose primary objective is to determine stellar energy distribution in the spectral region from 3000 to 800 Angstroms; (3) the Princeton Observatory experiment which includes a telescope ultraviolet spectrometer to collect data about the ultraviolet lines in the spectrum of O and B type stars.

The first astronomical observatory, OAO-A, placed in orbit April 8, 1966, was a great disappointment because overheating quickly destroyed its batteries. After intensive reassessment and redesign of the spacecraft, OAO II was launched December 7, 1968.

Full interpretation of results from OAO II will take at least two years. However, early results from the Wisconsin series of experiments indicate (1) unexpectedly intense ultraviolet light in some of the old galaxies such as M-31, the Andromeda galaxy, while other galaxies, e.g. M-82 and M-81, radiate less ultraviolet light than was expected and (2) total density of luminous matter in the universe is lower than necessary to support either the steady state or evolving closed universe theories of the universe. The mapping being done as a part of the Smithsonian experiment indicates that about one per cent of the observed stars are fainter in ultraviolet light than was predicted. Old theories will have to reconciled with these new data to produce new, more accurate, theories about the universe.

Activity

Assign research reports on topics such as the OAO, X-ray astronomy, gamma-ray astronomy, radio astronomy, infrared astronomy, etc.

Resource Materials

Books

Branley, Franklyn M., Exploration of the Moon. pp. 46-76. Data from moon probes.

Emme, Eugene M., A History of Space Flight. pp. 163-188. Projects Mercury, Gemini, and Apollo.

Friedman, Herbert, "The X-Ray Universe," The Earth in Space. Hugh Odishaw, (ed.). pp. 244-253. X-ray astronomy: its history and discoveries.

Goldenstein, Richard M., "Venus," The Earth in Space. Hugh Odishaw, (ed.). pp. 170-179. Description of Venus including Mariner data.

Haber, Heinz, Space Science. pp. 83-136. The sun and its study; description of Venus and Mars including Mariner spacecraft data; Surveyor and Lunar Orbiter programs; and studying the stars with orbiting observatories.

Hendrickson, Walter B. Jr., Satellites and What They Do. pp. 82-83, 244-245, 251-254. Description of OAO's; Gemini and Apollo programs.

Johnson, Francis S., "The Solar Wind in Space," The Earth in Space. Hugh Odishaw, (ed.). pp. 33-45. Description of the solar wind and its effect on earth.

Kay, Terence, Target: Moon. Ranger, Gemini and Apollo missions.

Kuiper, Gerard P., "The Lunar Surface," The Earth in Space. Hugh Odishaw, (ed.). pp. 146-156. Recent discoveries about the lunar surface.

Levitt, I. M. and Dandridge M. Cole, Exploring the Secrets of Space. pp. 167-170, 174-175. Descriptions of Project Mariner and Project Voyager.

Lundquist, Charles A., The Physics and Astronomy of Space Science. pp. 48-55, 59-61, 68-72, 85-90. The moon and conditions near the moon; the solar wind and Orbiting Solar Observatories; Venus as seen by Mariner II; Mars as seen by Mariner IV; Orbiting Astronautical Observatories.

Moore, Patrick and Peter J. Cattermole, The Craters of the Moon. Discussion, based on observational data, of the origin of the craters.

National Aeronautics and Space Administration, Exploration of the Moon, Curriculum Supplement. EPS-HISD-NASA #9500 Unmanned lunar spacecraft missions and results.

National Aeronautics and Space Administration., Gemini IX-A, Fact Sheet 291-F, August, 1966. Description of the mission and the crew.

_______, Gemini XI Mission, Fact Sheet 291-H, October, 1966. Description of the mission and the crew.

_______, Gemini XII Flight and Gemini Program Summary, Fact Sheet 291-I, December, 1966.

_______, "Interplanetary Explorer Satellites," NASA Facts. Vol. II, No. I. Solar wind, solar cosmic rays, solar flares.

_______, "Journey to the Moon," NASA Facts, NF-40/11-67. Pictorial chart.

_______, "Lunar Orbiter," NASA Facts. NF-32/Vol. IV, No. 4. Lunar orbiter mission and results.

_______, Lunar Photographic Missions, EPO 5/67. Photographs of the moon taken by Ranger, Surveyor, and Lunar Orbiter missions.

_______, "Manned Space Flight: Apollo," NASA Facts, NF-23/Vol. IV, No. 7. Description of flight program and spacecraft.

_______, "Manned Space Flight: Projects Mercury and Gemini," NASA Facts, Vol II, No. 8. Project Mercury; Gemini spacecraft and mission.

_______, "Mariner," NASA Facts. D-62. Description of Mariner spacecraft and its instruments; solar plasma detector.

_______, "Mariner IV," NASA Facts. Vol. II, No. 9. Description of Mariner IV and its mission.

_______, "Mariner Spacecraft; Planetary Trailblazers," NASA Facts. NF-39/2-68. Mariner spacecraft and their missions; Mariner V data about Venus.

_______, "Mariner II Reports," NASA Facts. NF B-4-63. Mariner II data on Venus.

_______, "Orbiting Solar Observatory," NASA Facts. Vol. III, No. 7. Description of the sun and solar observatories.

_______, "The Pioneer Spacecraft," NASA Facts. NF-31/Vol. IV. No. 3. Contents of interplanetary space.

_______, Project Gemini. Pictorial description of Gemini program.

_______, "Project Ranger," NASA Facts. Vol. III, No. 2. Ranger missions and their results.

_______, "Ranger Spacecraft," Educational Brief. 080265-HISD-EB-RB #10020.1. Ranger spacecraft and photographs of moon taken on Ranger missions.

National Aeronautics and Space Administration, "A Report from Mariner IV," *NASA Facts*. Vol. III, No. 3. Mariner IV data on Mars.

________, "Surveyor," *NASA Facts*. NF-35/Vol. IV, No. 6. Surveyor spacecraft, missions, and results.

Naugle, John E., *Unmanned Space Flight*. pp. 7-19, 29-36, 44-46, 103-162. Programs to study the sun and results of data collected; Ranger, Surveyor and Lunar Orbiter programs; exploring the planets; Mariner and Voyager programs; space astronomy; ultraviolet astronomy; OAO; astronomy experiments; X-ray astronomy; gamma-ray astronomy; radio astronomy.

Parker, E. N., "Sun and Earth," *The Earth in Space*. Hugh Odishaw, (ed.). pp. 46-56. The effect of the sun on Earth.

Sykes, J. B. (translator), *The Other Side of the Moon*. pp. 30-36. The unseen side of the moon.

Urey, Harold C., "The Moon," *The Earth in Space*. Hugh Odishaw, (ed.). pp. 136-145. Origin and surface of the moon.

Wise, Donald U., "Mars," *The Earth in Space*. Hugh Odishaw, (ed.). pp. 159-169. Description of Mars including Mariner data.

Films

Apollo Lunar Mission - Update (c, 17 min.) Basic lunar mission parameters; animated flight sequences.

Close-up of Mars (b/w, 30 min.) Mariner IV television camera; significance of first photographs of Mars' surface.

The Clouds of Venus (c, 29 min.) Mariner II information about Venus.

Destination Moon (c, 20 min.) Story of Ranger 7.

The First Soft Step (b/w, 28 min.) Mission and accomplishments of Surveyor program.

The Log of Mariner IV (c, 27 min.) Trajectory, photographs, scientific conclusions about Mariner-Mars flyby.

Lunar Bridgehead (b/w, 29 min.) Launch and flight of Ranger VIII.

Lunar Landing - The Mission of Surveyor I (c, 15 min.) Documentary on Surveyor I.

The Lunar Orbiter (c, 26 min.) Purposes of Lunar Orbiter flights; animation of flight.

Next . . . The Men (c, 19 min.) Story of Surveyor I; pictures of the moon.

One, One, Zero, Zero (c, 27 min.) Story of Surveyor I; moon surface photographs.

Project Mercury Summation (c, 29 min.) Summary of Mercury program achievements.

Ranger VIII Television Pictures of the Moon (b/w, 8 min.) Photographs taken February 17, 1965.

Ranger IX Photographs of the Moon (b/w, 7 min.) Photographs taken March 21, 1965.

Ranger 7-A Camera (b/w, 12 min.) Photographs taken by the A camera on Ranger 7.

Ranger VII Photographs of the Moon (b/w, 8 min.) Photographs, taken July 31, 1964, of moon's surface.

Seas of Infinity (c, 14 1/2 min.) Planning, development, launching and functioning of OAO.

Shoot the Moon (c, 28 min.) The moon as seen by Lunar Orbiter, Ranger, and Surveyor craft; summary of man's knowledge about the moon, its craters, soil and other significant features.

The Twelve Gemini (c, 20 min.) Summary of program objectives and scientific experiments.

Window on the Cosmos (b/w, 29 min.) The development, manufacture and mission of the OAO.

Other Media

Lunar photographs - 8 x 10 photographs of moon's surface taken by Ranger VIII.

NASA Photographs - Group E - Satellites and Space Probes - 8 x 10 photographs including Ranger and Surveyor I moon photographs.

Terrain Photos - Series of 5 transparencies - Includes moon photographs from Ranger and Lunar Orbiter; close-up of Crater Copernicus and Crater Alphonsus; includes surface photos of Mars taken in Mariner fly-by.

EARTH SCIENCE

Since the launching of the first satellite, great quantities of data have been collected about the planet earth. As a result, much more accurate information is available about its characteristics. Maps can be drawn more accurately, navigation can be more precise, and mineral deposits and other resources have been located. Scientists are able to identify types of soils, geological features, types of vegetation, characteristics of watersheds, and sources of fresh water from photographs taken by satellites. A fairly definitive picture of the earth's magnetosphere, whose very existence was unknown prior to the space age, is now available, and the investigation of that part of the earth's space environment, with its radiation belts and its interaction with solar plasma, has become a field of study all its own. Meterology has become a more exact science as meteorological satellite cameras photograph cloud patterns, and other sensing devices record information which can be correlated with the cloud patterns to aid in the forecasting of weather. Oceanography also benefits from the data collecting capabilities of satellites which can aid in the delineation of ocean currents, the mapping of surface temperatures and even location of schools of fish.

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GEODESY

Objective

To be able (1) to name the satellite programs for investigation of the earth and to describe their purposes and (2) to list information about the earth which has resulted from an interpretation of the data collected by the satellites.

Background Information

The results of space exploration have greatly increased our knowledge about the earth: its shape and size, its environment, its surface features. Accuracy in map making and precision in measurement of the earth's surface have been greatly facilitated as a result of the data collected by space probes, unmanned satellites, and manned satellites. Data collected by earth satellites can provide us with invaluable information about the geology of the earth, the location of natural resources, and even the extent to which these resources have been exploited and/or polluted by man. In the past, photographs taken from aircraft have provided us with much information; however, these photographs are necessarily limited in scope because of the altitude limitations of aircraft. One synoptic photograph from space can cover the same area covered by over 300 aerial photographs and present a clearer picture of large geographic features. In addition, ocean expanses, so difficult to reach for aerial photography, can be pictured in detail, and magnetometer readings can provide data for a three-dimensional mapping of the ocean floor.

Many of the earth's great ore deposits are associated with faults in the earth's crust. Space photography makes it much easier to trace these fault lines and thereby locate areas which may have great mineral potential. A new ore deposit in the southwestern part of the United States was located as a result of space photography. Delineation of rock structures by radar, which can penetrate vegetation, can aid in exploring for mineral deposits which are often located through identification of adjacent rock structures. Oil fields may be detected by photographs which reveal ocean surface seepage as areas of brine which have a high iodine concentration.

Infrared photography from space can be very useful in differentiating between arable and non-arable soils, in detecting changes which may be an indication of the onset of disease in forest or crop areas, in determining the biological and sedimentary content of bodies of water, and in the location of fresh groundwater which may be flowing into the ocean or trapped by faults in the earth's surface. Infrared imagery has revealed hot surface areas over hot water and steam in Yellowstone National Park and, thus, may be useful in location of geothermal power resources. The amount of sedimentation in reservoirs can be determined. Sources of water pollution can be located and the flow of the pollutants traced as they mix with the surrounding water which has a different temperature.

The surface of the earth deviates from the geoid which is the hypothetical form the earth would have if it were a smooth rotating sphere entirely covered by water. Variations in gravitational pull upon orbiting satellites indicate variations in the distribution of the earth's mass. Satellite data have indicated that the earth is more flattened at the South Pole than at the North Pole and that the equator rather than being circular is an ellipse. Far from being a smooth sphere, the earth has high areas and low areas which have resulted from differences in stresses inside the earth. These high areas are located (1) in the Pacific Ocean near Okinawa, (2) in the Pacific Ocean west of Peru, (3) in the Indian Ocean midway between Africa and Australia, and (4) in the Pacific Ocean south of the Aleutian Islands, and (5) in the Pacific Ocean midway between California and Hawaii.

The gravitational field of the earth and its geoid are closely related. Accurate information about the direction and magnitude of the force of gravity at any point in space is important to the calculation of the exact trajectory of satellites. A major contribution of satellite geodesy has been the delineation of the major features of the earth's gravity forcefield. One of the purposes of the GEOS satellite program has been to determine accurately the gravitational field of the earth.

Color photographs made on Gemini flights have been helpful in correcting geologic maps. Some results of the interpretation of these photographs are: (1) geologic structures and rock units never mapped before were shown in northern Baja California; (2) a major volcanic field of Quaternary age was discovered in Chihuahua, Mexico; (3) inaccuracies in topographic maps of Saudi Arabia were detected; (4) a large number of formerly unmapped geologic structures were shown in a major mining district of Southwest Africa; and (5) the regional distribution of the sand dunes in the Namib Desert was established.(Diamonds occur in the alluvium between the sand dunes).

Unmanned satellites are being used extensively to aid in correctly measuring and mapping the earth. Below is a listing of unmanned satellites and satellite programs used in making geodetic surveys.

Vanguard I - Launched March 17, 1958.

Observation of the deviations in the orbital path of Vanguard I led to the discovery that the earth, though flattened at both poles, is more flattened at the South than at the North Pole. Thus, the earth was called "pear-shaped," even though this flattening effect is so very slight that the earth still more nearly resembles a slightly flattened orange.

Vanguard I is being used in making measurements, by triangulation, for mapping the surface of the earth. Signals are beamed from two radio or radar stations to Vanguard, and the exact distances of the stations from the satellite are calculated. From this information, the exact distance between the stations can be calculated.

Anna 1B - Launched October 31, 1962.

Primarily a Defense Department project, though NASA was somewhat involved, Anna 1B was equipped with xenon flash tubes, which flash on for a millionth of a second every 5.6 seconds, to be photographed against the star background. Using the information obtained from the photographs and the measurement of the Doppler shift in the wavelength of signals transmitted from earth to Anna 1B's dual frequency transponder, scientists calculate the exact location of points on the surface of the earth.

The SECOR program (Sequential Collation of Range)

Secor satellites were included as part of Air Force multiple-satellite research and development launches. SECOR 1 was launched January 11, 1964. Several others in the series have since been launched to continue the geodetic survey of the earth. The Secor system measures electronically the distances between an Earth orbiting satellite and four ground stations, three of which have known geodetic coordinates. All four stations transmit signals to the satellite which retransmits these signals to the ground stations. The exact ranges to the known locations are computed and, by comparison, the exact range to the unknown location can be calculated. Secor measurements are extremely accurate and precise. Through use of this system a much more precise determination of the location of tracking stations was made, and errors in the mapping of the location of islands have been corrected.

PAGEOS (Passive Geodetic Earth-Orbiting Satellite)

Launched June 23, 1966, PAGEOS is a 100-foot mylar balloon satellite which carries no instruments but reflects the sun's light. Photographed against the star background from the dark side of the earth, by two or more cameras, its position can be used to calculate the exact location of each camera. The distance between two points 3000 miles apart can thus be measured with a possible error of only 32 feet. The PAGEOS mission is to be completed by 1971. During the mission, mapping of 69 triangles on the surface of the earth will be completed. The sides of these triangles will be used as base lines to aid in the determination of the precise size and shape of the earth.

U. S. Geodetic Satellite Program

The Geodetic satellite program is a joint effort of NASA and the Defense and Commerce Departments. Its purpose is to establish a system for relating all the datum lines of the world to the earth's common center of mass. Each point in this World Geodetic Reference System is expected to be located within 10 meters of its true location. By 1966, the relative positions of 12 of the necessary 75 control points had been precisely established. The first satellite in this series, the Explorer XXIX, also called Geodetic Explorer A or GEOS-1, was launched November 6, 1965. Geodetic equipment on GEOS-1 includes (1) optical beacons whose flashes can be photographed against the star background,

(2) quartz prisms for reflecting laser beams back to earth so that their travel times and angles can be determined, (3) a transponder for returning radio signals to Earth for analysis, (4) a Doppler beacon which transmits a radio wave from the satellite to the earth for gravimetric calculations, and (5) a range and rate system as a backup system to determine the satellite's speed and distance from a ground station. GEOS-2 (Explorer XXXVI), with a similar configuration, was launched January 11, 1968.

Activities

1. Obtain a copy of Aerial Stereo Photographs by Harold R. Wanless and demonstrate how stereo-aerial photographs can be used to study land forms, rock structures, vegetation, soils, etc.

2. Assign research projects on topics such as

   the Vanguard program, Anna satellites, the SECOR program, PAGEOS, the geodetic satellite program, etc.

OCEANOGRAPHY

Objective

To be able to list the possible benefits of exploration of the oceans by satellite.

Background Information

The capability of orbiting satellites for collecting data over vast areas may greatly facilitate the study of the oceans. Currents can be mapped, schools of fish can be located, and areas of high concentrations of plankton food for fish can be identified. Frequent mapping of the flow of the major ocean currents can aid the fishing industry in location of feeding grounds and, in addition, can aid in weather prediction and in navigation. Navigation routes through coastal and shoal waters can be mapped more accurately and in greater detail from space. Photographs, in addition to aiding in the mapping of navigation routes, can show where silt is building up in harbors and at river mouths.

With the aid of satellites, oceanographers hope to be able to collect data related to the oceans' salinity, their temperature differences, their chemical compositions, wave motion and height, and the biological activity in the oceans. Photographs taken during Gemini flights have already enabled oceanographers to obtain much information about ocean currents, plankton, shoals and other underwater features to a depth of about 100 feet. The Nimbus B IRLS (Interrogation, Recording, and Location System) will enable oceanographers to collect data from buoys moored or floating in the oceans and will provide opportunities for collecting and even wider range of information about the characteristics of the oceans.

Activity

Assign research topics such as the IRLS system, navigation by satellite, etc.

EARTH'S ATMOSPHERE

Objective

To be able to list new information about the earth's atmosphere which has been gathered through the use of satellites and space probes.

Background Information

During the International Geophysical Year (IGY), 1957-1958, intensive exploration of the earth's atmosphere, using sounding rockets and satellites, was initiated. Results have shown the upper atmosphere to be much more complex than formerly thought, with great variations in density and temperature. In addition, data have shown that, instead of being relatively shallow, the earth's atmosphere extends several Earth radii out into space with a diurnal bulge which is probably caused, in part, by the pull of the sun's gravity.

Energy absorbed from the sun heats the atmosphere, causing differences in temperature and density which result in mass air movements. The sun's energy also causes chemical changes by breaking down molecules and ionizing atoms and molecules.

Temperature of the atmosphere decreases to a low at about 8 miles from the earth, warms again to a maximum at 18 miles, cools again to a minimum at about 60 miles, and then increases very rapidly above 150 miles to as high as 2000° F. Because of the low temperature at the 60 mile level, almost all water is frozen out of the atmosphere, although a minute amount does rise higher where it is decomposed into oxygen and hydrogen by ultraviolet radiation. The chemical composition of the atmosphere above 100 kilometers is different from that of the lower atmosphere. Beginning at about the 100 kilometer level, the atmosphere is composed of nearly equal amounts of nitrogen and oxygen. As distance from Earth increases atomic oxygen, then atomic helium, and, finally, atomic hydrogen predominate in the atmosphere. Air density decreases with increasing altitude and varies from day to day, from day to night, and from place to place. An increase in air density follows a solar flare closely and air density fluctuates with the solar cycle. It is theorized that increased solar activity warms the upper atmosphere, causing it to expand into higher levels; with a decrease in solar activity the atmosphere contracts again to normal density levels.

Various Explorer satellites have been used to investigate phenomena of the atmosphere. The Air Density Explorers (IX, XIX, XXV, XXIV), lightweight inflated balloons, collected data relative to the number of particles per unit volume of atmosphere. The Atmospheric Explorers (XVII, XXXII) were launched to gather information about the density, composition, pressure and temperature of the atmosphere.

Explorer XVII data led to the discovery of the helium belt around the earth and Explorer XXXII data showed that changes in the atmosphere were related to solar storms. Topside Sounder (Explorer XX), Canada's Alouette 1 and 2, and the United Kingdom's ARIEL series have all collected data about the ionosphere from above the ionosphere. The Beacon Explorers (XXII, XXVII) have also been gathering information about the ionosphere. In addition to collecting data about the earth itself, the geodetic Explorers have gathered data about the earth's atmosphere.

Activity

Assign research topics such as the IGY, Explorer satellites, etc.

ATMOSPHERIC DENSITY

Objective

To be able to explain why (1) the density of the earth's atmosphere varies with altitude and (2) the atmospheres of planets of the solar system are not alike.

Background Information

Because gravitational attraction varies with altitude, the density of the earth's atmosphere varies exponentially with the distance from the surface of the earth. For any increase of 18,000 feet in distance from the earth's surface, the density of the atmosphere decreases to approximately one-half that of the altitude from which the distance is measured. Density of the lower atmosphere, that is, up to 100 miles altitude, has been successfully measured by using sounding rockets. An analysis of data about the drag effect of the atmosphere upon satellites in orbit has been the source of information about the density of the atmosphere above 100 miles altitude. These calculations are, at best, only approximations (possible error of ± 20 per cent) because of numerous possibilities for inaccuracy in calculating an exact measurement of drag upon the nonspherical surface of satellites.

Atmospheric density also varies with the amount of solar activity. A definite cyclical change in the density of the earth's atmosphere has been correlated with the 28-day rotational period of the sun. In addition, during solar flares definite changes in the density of the atmosphere are noted. According to present theory, the heating of the atmosphere during periods of greater solar activity causes an expansion of the atmosphere and results temporarily in greater atmospheric densities occurring at higher altitudes.

Two factors affect the capability of a planet to retain an atmosphere: the surface gravity of the planet and the amount of heat resulting from solar radiation. The mass of the planet determines the amount of its gravitational attraction for individual gas atoms and molecules. A large planet, with a strong gravitational field, may retain many of even the lightest gas molecules. However, smaller planets, over a period of time, have lost the lighter molecules which can easily escape the planet's gravitational field. The rate of molecular movement on a planet is affected by the amount of solar radiation received and therefore the amount of heating of the atmosphere. Planets closer to the sun would be expected to have more highly heated atmospheres and therefore relatively more actively moving molecules within that atmosphere. The more active the molecular movement is, the greater possibilities there are for the molecules to escape the control of that planet's gravitational field. As a result, in general, it is hypothesized that the small members of the solar system, which are relatively nearer the sun, are incapable of retaining an atmosphere.

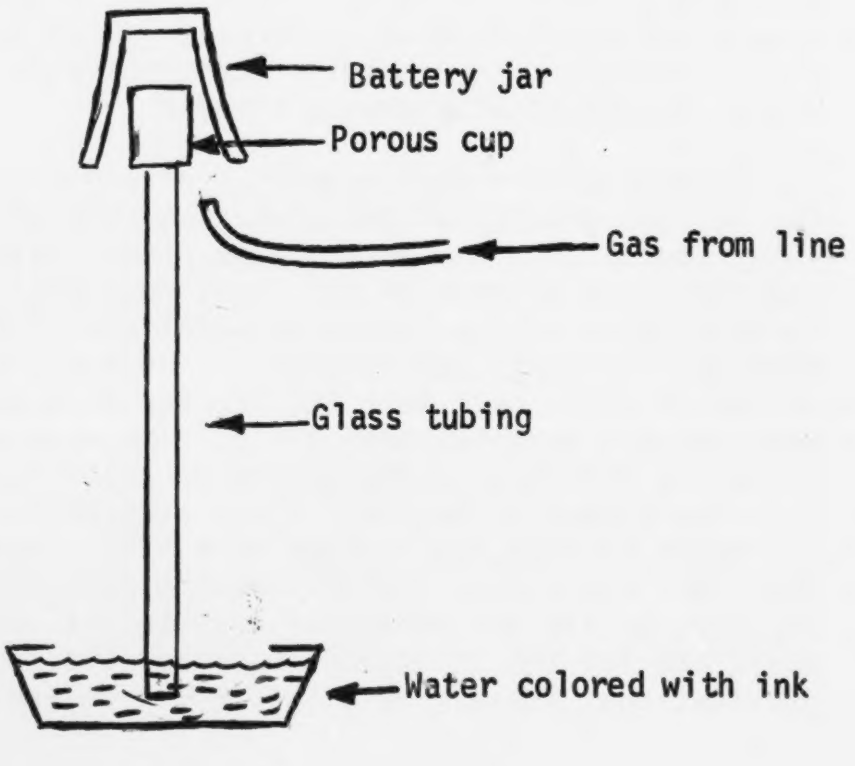
Activity

Demonstrate the differences in the rates of gas diffusion from a planetary surface.

Materials needed:

- Battery jar
- Porous cup
- Glass tubing
- One-hole stopper
- Rubber tubing
- Sources of different gases

Place the one-hole stopper on one end of the glass tubing. Insert the stopper into the porous cup. Support the porous cup so that the other end of the glass tubing is immersed in the colored water. See illustration. Hold a battery jar over the porous cup. Release gas inside the battery jar. Bubbles will emerge from the bottom of the glass tubing while the gas is being released. When the gas is turned off, water will rise in the glass tube. The water will rise to different levels depending upon the type of gas released and the gas pressure.



METEOROLOGY

Objective

To be able to describe the meteorological satellite programs.

Background Information

Weather forecasting and weather research depend on the use of a combination of surface weather stations, radiosondes, weather reconnaissance aircraft, weather radar, weather ships, and, the latest tool, weather satellites. The latter have almost revolutionized weather research and weather forecasting; however, even observations by weather satellites must be interpreted by man, often with the aid of computers, and must be supplemented by information from other more prosaic instruments.

Probably the first meteorologist to realize the possibilities of using pictures of clouds for forecasting weather was D. L. Crowson of the U. S. Air Force whose article suggesting the use of television cameras in rockets was published in 1949. Later, a secret air force study of the military uses of satellites included a suggestion for using satellites to observe cloud cover. Rocket photographs of cloud cover were made from time to time at White Sands. In 1957, H. Wexler, decribed the appearance of the typical cloud cover over the United States as he thought it would appear if photographed from a satellite.

With the advent of Sputnik, the Advanced Research Projects Agency was set up in the Department of Defense, and it was decided that a meteorological satellite program would be an appropriate part of the U. S. space program. Early Vanguard and Explorer satellites included experiments which contributed to the knowledge needed to make the first meteorological satellite launching relatively successful. Two basic types of information are collected by meteorological satellites: (1) television pictures of the earth's surface and cloud cover and (2) infrared measurements of the earth's radiation at several different wavelengths.

The TIROS (Television Infra-Red Observation Satellite) program, consisting of ten satellites launched between April 1, 1960 and July 2, 1965, proved beyond doubt that meteorological satellites were not only feasible, but also very useful for weather observation, and that data from satellites could be used for daily weather analyses. Television pictures transmitted by the satellites have made it possible to identify cloud patterns typical of cyclonic air movements, hurricanes, typhoons, etc.

Automatic Picture Transmission (APT) was inaugurated with the launch of TIROS VIII and TIROS IX. Prior to that, pictures from the satellites were displayed on a television screen and then photographed. The APT system permits transmission of pictures directly, as in radio photography. Anyone with relatively simple receiving equipment can receive the pictures transmitted.

NASA's Project Nimbus was designed to test advanced equipment for use in a weather satellite system. Nimbus I (Nimbus A) was launched August 28, 1964; Nimbus II (Nimbus C), May 15, 1966. Night pictures, made possible by the use of a High-Resolution Infrared Radiometer (HRIR) system, depict the slight differences in heat radiation from clouds and from the earth's surface. Nimbus is also equipped with an Advanced Vidicon Camera System (AVCS) which consists of three small television cameras operating simultaneously to produce one long three-panel photograph. The APT system on Nimbus can provide a local weather station with as many as 15 pictures daily of an area of over 750,000 square miles.

Nimbus B is the most advanced of NASA meteorological satellites. It is planned to carry several experiments which may have potential for improving weather forecasting. New experiments included on the Nimbus B are the Infrared Interferometer Spectrometer (IRIS) and a Satellite Infrared Spectrometer (SIRS). These sensors are designed to gather data about the vertical temperature of the earth's atmosphere, about its water vapor content, the ozone distribution, and the dispersion of air pollutants. An Image Dissector Camera System (IDCS) is expected to provide improved camera coverage of local cloud formations. Nimbus B failed to orbit on May 18, 1968, when the booster guidance malfunctioned. Nimbus B-2 is scheduled to orbit sometime in the summer of 1969.

The United States now has an operational meteorological satellite system, designed and launched by NASA, but managed and operated by the Department of Commerce and the Environmental Science Services Administration. This system, called the TIROS Operational Satellite system (TOS), was initiated with the launch of ESSA 1 on February 3, 1966. The ESSA spacecraft have the general conformation of the TIROS satellites, however, they are launched to roll cartwheel fashion around the earth in a nearly polar, sun-synchronous orbit. In this orbit, the satellite views the weather everywhere over the earth once every 24 hours and takes pictures of a given area at the same local time each day. ESSA satellites are equipped with two optical systems: (1) an APT system which continuously transmits pictures to any receiving station in line-of-sight range and (2) an AVCS system which stores television picture data for transmission to ground facilities on command. Data is relayed to ESSA's National Environmental Satellite Center at Suitland, Maryland,where, with the aid of a computer, cloud mosaics are constructed.

Horizontal sounding balloons also play a part in assessing the complete weather picture. The National Center for Atmospheric Research is developing a series of upper air sensor platforms. These are non-extensible balloons with a predetermined inside pressure which causes them to float around the earth at a specified density level. These balloons, carrying sensors to measure pressure, temperature, and water vapor, are equipped with a transponder for transmitting this information to ground stations.

NASA's Applications Technology Satellite series (ATS), designed to test components and techniques for future meteorological, communication, and navigational satellites, are also providing meteorologists with a series of cloud photographs. A color Spin-Scan Cloud Camera (SSCC) provided the first color pictures of earth from ATS 3 on November 8, 1967.

Activities

1. Assign research topics such as the TIROS satellites, Application Technology Satellites, the Nimbus program, ESSA, Automatic Picture Transmission, the TOS system, etc.

2. As a class project build an automatic picture transmission ground station which can receive cloud pictures from the ESSA satellites. See NASA, "How to Build Inexpensive APT Ground Stations".

MAGNETOSPHERE

Objective

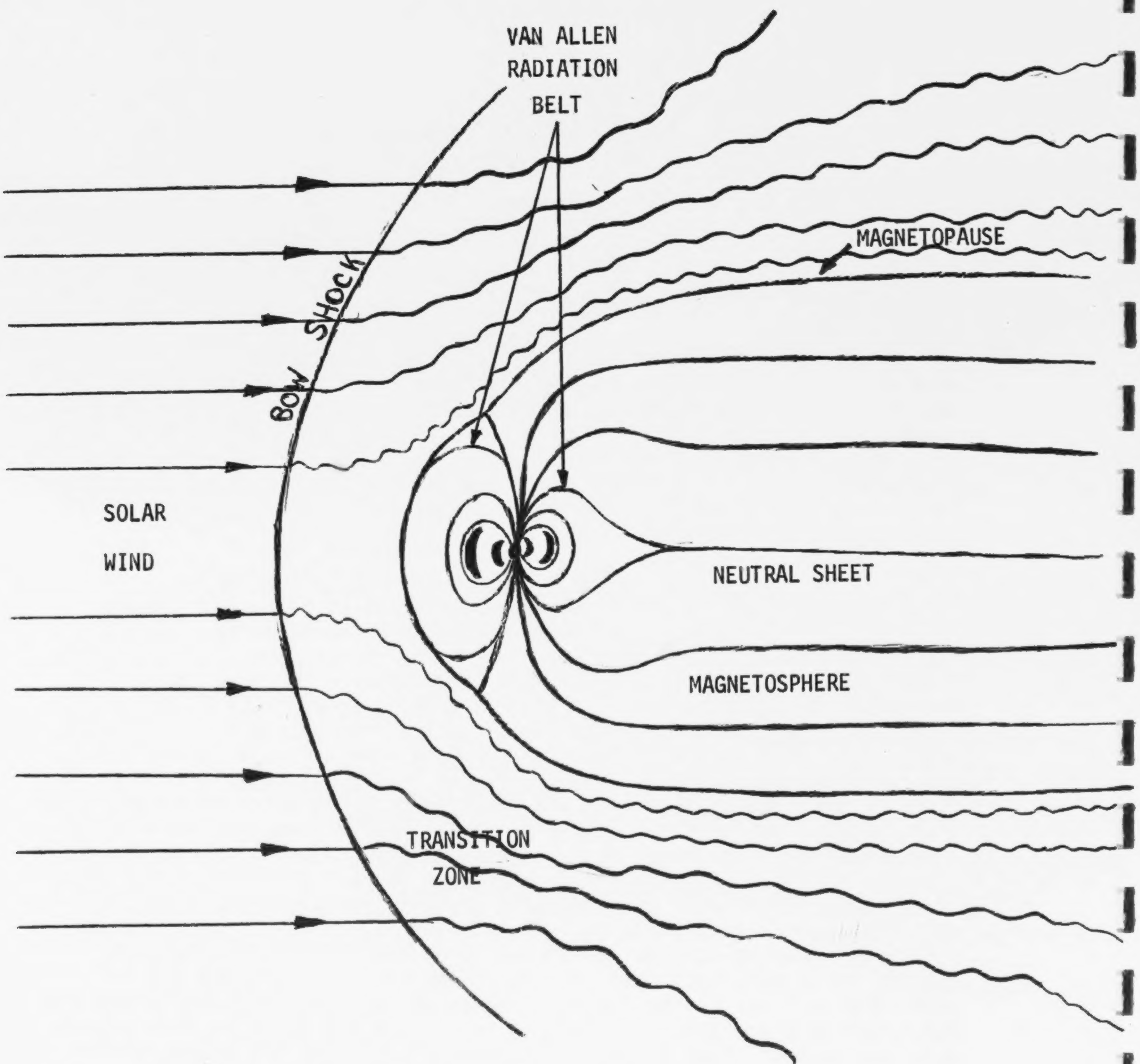
To be able (1) to describe the earth's magnetosphere and (2) to list results of the Explorer satellite program to collect data about the magnetosphere.

Background Information

For centuries man has known that the earth has a magnetic field, with the earth's axis approximately the dipole of the field. With the coming of the space age it was suddenly, unexpectedly, discovered that this magnetic field, the magnetosphere, reacted with solar and cosmic radiation to form the now famous Van Allen belts. As more satellites have been orbited, a more definitive picture of the earth's magnetosphere has developed. Latest information indicated that this comet-shaped field appears approximately as is shown in the diagram Page

Cosmic radiation trapped in the magnetosphere consists of protons and electrons which spiral around the magnetic lines of force and "bounce" back and forth between the northern and southern hemispheres. In addition to this north-south movement, protons drift westward while electrons drift eastward around the earth. The magnetosphere begins at about 100 kilometers from the earth's surface and extends to at least 50,000 kilometers. On the sun side, the distance varies from 50,000 to 80,000 kilometers depending upon the amount of pressure from the solar wind. At the point where solar radiation compresses on the sun side, the lines of force formed between the north and south poles are similar to those around a bar magnet, while on the dark side, the lines of force run parallel to each other out into space, with a plasma-filled neutral zone, called the "neutral sheet," lying between the opposing lines. The drag of the solar wind causes this "tail" which extends outward from the earth a distance which has been estimated to be from 1 to 10 million kilometers, perhaps even more. During periods of intense solar radiation following solar flares, it is theorized that the drag of the solar wind along the tail pulls the tail out so far that it becomes unstable and magnetic lines from the south pole are able to link with those from the north to form greatly extended loops. These field lines contract and force the plasma within the neutral sheet into the atmosphere and into the radiation belts, greatly intensifying activity in the auroral displays and greatly enhancing the total energy of the radiation belts.

Most of the exploration of the magnetosphere has been done by electronic detectors on Explorer satellites; however, nuclear emulsions on sounding rockets have also been used to collect data. In addition to the Explorer satellites, many other satellite instrument packages have included devices which collect data about the magnetosphere.


VAN ALLEN
RADIATION
BELT
MAGNETOPAUSE
BOW SHOCK
SOLAR
WIND
NEUTRAL SHEET
MAGNETOSPHERE
TRANSITION
ZONE

Among these satellites are the Orbiting Geophysical Observatories, Mariner satellites, and Pioneer satellites. Following is a listing of some of the Explorer satellites and their major contributions to knowledge about the magnetosphere.

Explorer I, launched January 31, 1958, found huge pockets of high energy protons and electrons trapped in the earth's magnetosphere (the Van Allen belts).

Explorer IV, launched July 26, 1958, collected data which indicated that radiation from atomic explosions is trapped in the magnetosphere.

Explorer VI, launched August 7, 1959, detected an electric current, caused by the earth's magnetic field flowing westward between 25,000 and 40,000 miles from earth.

Explorer VII, launched October 13, 1959, proved that the trapping of radiation by the magnetosphere is associated with the auroral activity. Its data also indicated fluctuations and movement in the outer Van Allen belt.

Explorer X, launched March 25, 1961, provided information about the relationship between solar flares and activity in the earth's magnetosphere. The rubidium magnetometer was used in this satellite for the first time.

Explorer XII, launched April 15, 1961, was the first of the Energetic Particle Explorers whose primary mission was to collect data about natural and artificial radiation belts.

Explorer XVII, launched April 2, 1963, discovered a belt of neutral helium particles around the earth.

Explorer XVIII, launched November 26, 1963, was the first of the interplanetary explorers whose primary mission was the study of the cislunar radiation environment. It provided information about the shock wave formed ahead of the magnetosphere as it meets the solar wind and about the region of turbulence between the shock wave and the edge of the magnetosphere.

Explorer XXXIII, launched July 1, 1966, also known as the Anchored Interplanetary Monitoring Platform (AIMP), orbited the earth and the moon together and collected data about the cislunar radiation environment.

Activity

Assign research topics such as the Van Allen belts, the solar wind, OGO, the Explorer satellites, etc.

Resource Materials

Books

Ahrendt, Myrl H., The Mathematics of Space Exploration. pp. 37-42. Earth's atmosphere.

Axford, W. I., "The Magnetosphere," The Earth in Space. Hugh Odishaw, (ed.). pp. 117-125. Discovery, description and interaction with solar wind described.

Bowhill, S. A., "The Ionized Atmosphere," The Earth in Space. Hugh Odishaw, (ed.). pp. 108-116. Description of the layers of the ionosphere.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 457-473. Structure of the atmosphere.

Haber, Heinz, Space Science. pp. 61-78, 96-100, 144-149. The earth: its size and its gravitational field; troposphere, ionosphere, stratosphere, and exosphere; temperature, air movement, radiation; description of the magnetosphere; weather satellites and how they aid the meteorologist.

Hendrickson, Walter B., Jr., Satellites and What They Do. pp. 31-33, 42-47, 56-59, 63-64, 74, 79-82, 151-168, 177-178. Missions of the Vanguard I, Orbiting Geophysical Observatories, and Anna I-B; Explorer VI, Explorer X, Vanguard III, Explorer XII, and Explorer XV and their roles in measuring the magnetosphere; data about individual weather satellites.

Huber, Lester F. and Paul E. Lehr, Weather Satellites. First five years of weather satellites; use of satellite data in forecasting and in research; future plans for use of weather satellites.

Kaula, W. M., "The Earth From Space," The Earth in Space. Hugh Odishaw, (ed.). pp. 126-135. Discoveries about the shape of the earth.

Lundquist, Charles A., The Physics and Astronomy of Space Science. pp. 20-28, 29-32, 78-80. The high atmosphere and the ionosphere; a technical discussion of the magnetosphere; kinds of data collected by meteorological satellites and how it is used; density of the high atmosphere.

"NASA's Nimbus B, Advanced Meteorological Satellite," Space World, Vol. E-9-57. pp. 5-26.

National Aeronautics and Space Administration, "A-R-I-E-L: First International Satellite," NASA Facts. C-62. Objectives of Ariel; participants in program.

National Aeronautics and Space Administration, "Explorer XIX; The Air Density Satellite," *NASA Facts*. Vol. II-2 Description of spacecraft; launch and orbital information.

________, "Explorer XXIX (The Geodetic Explorer)," *NASA Facts*. Vol. III, No. 4. Description of the satellite and its mission.

________, "How to Build Inexpensive APT Ground Stations," *Technology Utilization Pamphlet*, NASA - ST 5079.

________, "Interplanetary Explorer Satellites," *NASA Facts*. Vol. II, No. 1. Explorer satellite missions and preliminary results of these flights.

________, *The Meteorological Satellite Program: Keeping a Weather Eye Out in Space*. Achievements of TIROS and Nimbus programs.

________, "Nimbus," *NASA Facts*. Vol. II, No. 7. Project Nimbus, Automatic Picture Transmission system, satellite description and orbital information.

________, "Orbiting Geophysical Observatory," *NASA Facts*. Vol. II, No. 13. Description of the satellite and its purposes.

________, "TIROS," *NASA Facts*. Vol. II, No. 12. TIROS system, data acquisition and utilization.

Naugle, John E., *Unmanned Space Flight*. pp. 57-74, 76-94, 95-102. Atmosphere, ionosphere, upper atmosphere; flight programs to study the atmosphere; description of the magnetosphere and how this description has changed as more has been discovered; determining the size and shape of the earth.

Parker, E. N., "Sun and Earth," *The Earth in Space*. Hugh Odishaw, (ed.). pp. 50-51. Description of the magnetosphere.

Pieper, George F., "Appendix IV. The Solar Wind and the Earth's magnetosphere," *NASA's Space Science and Applications Program*. Homer E. Newell. pp. 480-494. The solar wind, the magnetosphere; a list of unanswered questions about each.

Sutton, Richard M., *The Physics of Space*. pp. 123-127, 65-70. Atmospheric density on planets.

Thompson, Philip D., Robert O'Brien, and the editors of *Life*, *Weather*. pp. 153-159, 176-178, 180-181, 184-187. Weather Bureau's National Meteorological Center; satellites as a tool for weather forecasting.

von Arx, W. S., "The Ocean," *The Earth in Space*. Hugh Odishaw, (ed.). pp. 88-96. Characteristics of the oceans; possibilities for using satellites to gather data about the ocean.

Wanless, Harold R., Aerial Stereo Photographs

Widger, William K., Jr., Meteorological Satellites. History of meteorological satellites, TIROS and Nimbus specifications, weather forecasting, research use of data.

Films

Atmospheric Pressure (b/w, 11 min.) Problems and discoveries of Von Guericke.

Exploring the Magnetosphere and Beyond (c, 29 min.) Magnetic fields; size and shape of magnetosphere.

A New Look at an Old Planet (c, 26 min.) Benefits of weather, communications, navigational and earth resources satellites.

Streetcar in the Sky (c, 8 min.) Functions and operation of OGO satellites.

Filmstrips

Earth's Magnetism

UNITS OF MEASUREMENT

Until the time comes that the United States abandons the English system of weights, and measures, its citizens need to be able to convert from one system to the other. Most scientists today, even in the United States, use the metric system of measurement to record their data and to make calculations. The space age has also fostered a change in the system of mathematical notation with which the average citizen is familiar. The need to record and use astronomically large and infinitesimally small measurements has led to the development and the use of scientific notation as a convenience in making calculations and in reading data. To be able to understand data presented in current reading materials a knowledge of the metric system and of scientific notation is valuable.

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METRIC SYSTEM

Objective

To gain facility in converting from the metric system to the English system of measurement and vice versa.

Background Information

In most countries around the world, the metric system of weights and measures is used by everyone. However, in the United States, the English system is the official system of weights and measures, and scientists and engineers, who use the metric system, must change English system measurements into those of the metric system, and vice versa.

The basic unit of length in the metric system is the meter.

1 meter ≈ 39.4 inches

1 foot ≈ .3 meter

1 inch ≈ .025 meter, 2.54 centimeters, or 25.4 millimeters

In the United States we measure distances in terms of miles (5,280 feet). In countries where the metric system is used, distances are usually measured in kilometers (1,000 meters). Kilo is the Greek word for one thousand.

1 kilometer (km) ≈ .62 mile

1 mile ≈ 1.6 kilometers

For weights that we would ordinarily express in pounds, people using the metric system use kilograms (1,000 grams).

1 kilogram (kg) ≈ 2.2 pounds

1 pound ≈ .45 kilogram

Activities

1. The meter is about ______ inches longer than the yard.
2. One yard = 3 feet ≈ ______ meter.
3. The payload of Explorer IX was a sphere which, when inflated, had a diameter of 3.7 meters. Express that diameter in inches, to the nearest inch.

4. Express the diameter of the inflated sphere carried by Explorer IX in feet and inches.

5. The United States and the United Kingdom cooperated in launching Ariel to study the ionosphere. Ariel was shaped like a cylinder, about .59 meter in diameter. Express the diameter of Ariel in inches (to the nearest inch).

6. Launch vehicle for Ariel was a 3-stage Delta booster, which stands 92 feet or about ______ meters high.

7. Vanguard I is a sphere whose diameter is about 6 inches; that is about ______ meter.

8. Echo I had a diameter of 100 feet, or approximately ______ meters. It was sent aloft in a container that was 26.5 inches or ______ (nearest hundredth) meter in width.

9. The zodiacal light is believed to be caused by the reflection of sunlight by a ring of small dust particles around the sun. If these dust particles range in size from 0.001 to 1 millimeter in diameter, what is this range of size in (a) centimeters, and (b) inches?

10. The passive satellite, Echo II, has a skin approximately 0.0007 of an inch thick. What is this thickness in (a) centimeters, and (b) millimeters?

11. How many meters in

    (a) 2 kilometers?
    (b) 10 kilometers?
    (c) 1/2 kilometer?
    (d) 1/4 kilometer?

12. How many kilometers in

    (a) 5 miles?
    (b) 10 miles?
    (c) 200 miles?
    (d) 325 miles?

13. Explorer IX had a perigee distance of 395 miles and an apogee distance of 1,605 miles. Express Explorer IX's perigee and apogee distances in kilometers.

14. Explorer X had a perigee distance of 100 miles and an apogee distance of 186,000 miles. Express these two distances in kilometers.

15. Ariel had a perigee distance of 390.5 km and an apogee distance of 1,216.5 km. Express Ariel's perigee and apogee distances in miles (to the nearest mile).

16. If the diameter of the nucleus of a comet is 1.4 kilometers, what is this diameter in

    (a) meters?
    (b) feet?
    (c) miles?

17. TIROS I (Television InfraRed Observation Satellite) transmitted weather information to receivers on the earth from an orbit which ranged from 428.7 to 465.9 miles above the earth's surface. What was this distance range in

    (a) kilometers? (b) meters?

18. Echo II is a passive satellite which merely reflects radio waves sent to it instead of relaying information by receiving and transmitting it, as does an active-repeater satellite. Echo II has a diameter of approximately 135 feet. What is this diameter expressed in meters?

19. If the diameter of white dwarf stars is generally between 1/3 and 2 times the earth's diameter (7,900 miles), what is the range of their sizes in kilometers?

20. The visible diameter of the sun is approximately 864,000 miles. What is the visible diameter of the sun in kilometers?

21. Betelgeuse, a red giant star, has a diameter about 350 times the diameter of the sun (864,000 miles). What is the diameter of Betelgeuse in kilometers?

22. The earth's magnetic field blends with the interplanetary magnetic field at about 100,000 kilometers above the earth's surface. What is this distance in miles?

Sounding rockets are designed to explore as far as 4000 miles away from the surface of the earth. While most of the rockets have been launched to explore the region of the atmosphere which lies from 20 to 200 miles away, multiple staging has made it possible to send probes much further into space. Sounding rockets are economical, simple, and reliable, but the data which they collect is necessarily restricted to a limited region at a specific time.

23. After World War II, several captured German V-2 rockets were launched to altitudes of about 120 to 160 kilometers. This is about how many miles?

24. Around 1949, after the captured V-2 rockets were expended, Aerobee rockets came into use. These rockets carried instruments which collected valuable data about atmospheric pressure, temperature, and density up to altitudes of approximately 150 kilometers. How many miles is this above the surface of the earth?

25. A larger rocket, named the Viking, capable of carrying heavy payloads to higher altitudes, was developed especially for sounding purposes. The Viking could reach an altitude of nearly 250 kilometers. What is this altitude expressed in miles?

26. Before rockets were used, meteorologists had to infer the physical properties of the upper atmosphere from ground observations and balloons which rose to about 30 kilometers. How many miles is this?

27. Complete the following:

(a) 10 kg ≈ ______ lb.　　(c) 200 kg ≈ ______ lb.

(b) ______ kg ≈ 22 lb.　　(d) ______ kg ≈ 6 lb.

28. Alouette is the name of a 320-lb. satellite which the United States launched for Canadian scientists. What was Alouette's weight in kilograms?

29. Ariel II weighed 68 kg. Express that weight to the nearest pound.

30. Explorer X weighed about 79 lb. Express that weight to the nearest kilogram.

31. TIROS is short for Television InfraRed Observation Satellite. TIROS satellites are shaped like giant pill boxes, 42 inches (______ meters) in diameter and ______ inches (.482 meter) high. TIROS 5 weighed approximately 285 lb. (______ kg). As TIROS 5 orbited at a perigee distance of 367 miles (______ km) and an apogee distance of ______ miles (974.2 km) it sent weather data back to Earth. One of its two television cameras had a wide-angle lens that took a picture of more than 600,000 square miles (______ sq. km.) at a time. (1 square km. ≈ .3861 sq. mi.)

Answers

1. 3.4
2. .9
3. 145.78 ≈ 146
4. 12' 2"
5. 23
6. 27.6
7. .15
8. 30; .66
9. (a) 0.0001 to 0.1
    (b) 0.000039 to 0.039
10. (a) 0.001778
    (b) 0.01778
11. (a) 2,000　(c) 500
    (b) 10,000　(d) 250
12. (a) 8　(c) 320
    (b) 16　(d) 520
13. 632; 2,568
14. 160; 297,600
15. 242; 754
16. (a) 1,400　(c) 0.868
    (b) 4,583
17. (a) 685.92--745.44
    (b) 685,920--745,440
18. 40.5
19. 4213.3--25,280
20. 1,382,400
21. 483,840,000
22. 62,000
23. 74.4 to 99.2
24. 93
25. 155
26. 18.6
27. (a) 22　(c) 440
    (b) 10　(d) 2.7
28. 144
29. 150
30. 36
31. 1.05; 19.2; 128.25;
    587.2; 604.0; 1,554,001.6

SCIENTIFIC NOTATION

Objective

To gain facility in writing very large and very small amounts in scientific notation and vice versa.

Background Information

Much scientific exploration would be impossible without numbers and mathematics. Computation with very large numbers, as in the measurement of stellar distances, and very small numbers, as in the measurement of atomic distances, is facilitated by the use of scientific notation in which numbers are expressed as powers of 10, with only one digit to the left of the decimal point.

Examples. $300 = 3 \times 10^2$

$2,000,000 = 2 \times 10^6$

$1,500 = 1.5 \times 10^3$

When using scientific notation, if the number is less than 1 the exponent will be negative : 1/10 (.1) is written 10^{-1}, 1/100 (.01) as 10^{-2} and so on. When the exponent is negative it indicates that the decimal point must be moved to the left that number of places. For example 2.15 x 1/100 would be written as 0.0215. In the same manner, 2.54×10^{-6} would indicate .00000254.

Activities

1. Mars is more than 100,000,000 miles from the sun. Express 100,000,000 as a power of ten -- that is, as 10 with some exponent.
2. The star nearest to us is the sun. The next nearest star is about 25 trillion miles away. Write the number, one trillion, in the usual way, and also as a power of ten.
3. Write the following as powers of ten:
   (a) one thousand thousands
   (b) one thousand millions.
   (c) one thousand billions.
4. The mean distance between Earth and the sun is about 93,000,000 miles. Write 93,000,000 in scientific notation.

5. Neptune has a diameter of about 30,000 miles. Write 30,000 in scientific notation.

6. Mercury has a diameter of about 3,000 miles Write 3,000 in scientific notation.

7. On a clear night you can see the Andromeda galaxy, a great collection of stars, which is 9,000,000,000,000,000,000 miles away. Use scientific notation to write this numeral.

8. From the earth, the closest visible star, other than the sun, is Alpha Centauri which is 25,240,000,000,000 miles away. Write that number in scientific notation.

9. Complete the following table.

	Mean Distance in Miles	Mean Distance in Miles (scientific notation)
Mercury	36,000,000	
Venus	67,000,000	
Earth	93,000,000	
Mars	142,000,000	
Jupiter	484,000,000	
Saturn	887,000,000	
Uranus	1,790,000,000	
Neptune	2,794,000,000	
Pluto	3,687,000,000	

10. Light travels approximately 186,000 miles per second or 5,900,000,000 miles in one year. Write these terms in scientific notation.

11. Sirius and Canopus appear, to the unaided eye, to be the brightest stars in the sky. They are 51,000,000,000,000 and 587,000,000,000,000 miles from Earth, respectively. Write these distances in scientific notation.

12. Just as there are very large distances in space, there are also tremendous masses in space. The mass of a body is the amount of matter contained in a body. The masses of members of the Solar System are given in the table below. Complete the table.

Object	Mass in billion, billion tons	Mass in scientific notation
Mercury	360	
Venus	5,370	
Earth	6,590	
Mars	709	
Jupiter	2,090,000	
Saturn	627,000	
Uranus	96,000	
Neptune	112,000	
Pluto	5,270	
Sun	2,200,000,000	
Moon	81	

13. For practice with small numbers, complete the following expressions:

(a) $0.00001 = ? \times 10^?$

(b) $0.00065 = ? \times 10^?$

(c) $6.15 \times 10^{-8} =$

(d) $5.06 \times 10^{-8} =$

(e) $3.45 \times 10^{-6} =$

(f) $0.0000001 = ? \times 10^?$

14. For an overall review, complete the following.

(a) $30{,}000 =$
(b) $700 =$
(c) $900{,}000 =$
(d) $40 =$
(e) $10^{-6} =$
(f) $10^6 =$
(g) $10^8 =$

(h) $10^{-8} =$
(i) $2.541 \times 10^{-5} =$
(j) $7 \times 10^7 =$
(k) $8 \times 10^{-8} =$
(l) $3.546 \times 10^{-15} =$
(m) 1 million = $? \times 10^?$
(n) 1/10 million = one ten millionth = $? \times 10^?$

15. An atom of hydrogen has a weight of about 0.00000000000000000000000166 grams. Write this numeral in scientific notation.

16. The diameter of an atom is 1×10^{-8} cm. The nucleus of an atom is about 1/10,000 of the diameter of the atom. Write in scientific notation the numeral which represents the diameter of the nucleus.

17. The electron weighs approximately 1/1840 that of a hydrogen atom, or 9.107×10^{-28} grams. This number is in scientific notation. Write it in the usual notation.

18. Explorer X's apogee distance (186,000 miles) was approximately $3 \times 10^?$ km.

19. Use scientific notation to express the apogee distance of Explorer X in meters: $3 \times 10^?$ meters.

20. The mean distance of Neptune from the sun is approximately 2,793,000,000 miles or 2.793×10^9 miles. If 1 light year is 5.88×10^{12} miles, how many light years is Neptune from the sun?

Answers

1. 10^8

2. 10^{12}; 1,000,000,000,000

3. (a) 10^6; (b) 10^9; (c) 10^{12}

4. 9.3×10^7

5. 3×10^4

6. 3×10^{3}

7. 9×10^{18}

8. 2.524×10^{13}

9. 3.6×10^{7}--Mercury
6.7×10^{7}--Venus
9.3×10^{7}--Earth
1.42×10^{8}--Mars
4.84×10^{8}--Jupiter
8.87×10^{8}--Saturn
1.79×10^{9}--Uranus
2.794×10^{9}--Neptune
3.687×10^{9}--Pluto

10. 1.86×10^{5}; 5.9×10^{12}

11. 5.1×10^{13}; 5.87×10^{14}

12. 3.6×10^{20}--Mercury
5.37×10^{21}--Venus
6.59×10^{21}--Earth
2.2×10^{27}--Sun
7.09×10^{20}--Mars
2.09×10^{24}--Jupiter
6.27×10^{23}--Saturn
8.1×10^{19}--Moon
9.6×10^{22}--Uranus
1.12×10^{23}--Neptune
5.27×10^{21}--Pluto

13. (a) 1×10^{-5}
(b) 6.5×10^{-4}
(c) 0.0000000615
(d) 0.0000000506
(e) 0.00000345
(f) 1×10^{-7}

14. (a) 3×10^{4}
(b) 7×10^{2}
(c) 9×10^{5}
(d) 4×10^{1}
(e) 0.000001
(f) 1,000,000
(g) 100,000,000
(h) 0.00000001
(i) 0.00002541
(j) 70,000,000
(k) 0.00000008
(l) 0.000000000000003546
(m) 1×10^{6}
(n) 1×10^{-7}

15. 1.66×10^{-24}

16. 1×10^{-12}

17. 0.0000000000000000000000000009107

18. 3×10^{5}

19. 3×10^{8}

20. 4.8×10^{-4}

MECHANICS

The gravitational attraction of a primary not only influences the path of a moving body, but also determines its weight, the centripetal force exerted upon it, and the amount of stress it undergoes at acceleration. According to Newton's calculations, any object moving under the influence of a gravity field must follow a path that can be represented by a conic section. Therefore the paths of satellites could become hyperbolas, parabolas, or ellipses depending upon velocity, altitude, and angle of injection.

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ORBITS AND TRAJECTORIES

Objectives

To be able (1) to explain how a spacecraft remains in orbit, (2) to list and describe the three factors which affect the shape of the path followed by a space vehicle, (3) to explain what escape velocity is, and (4) to describe a Hohmann transfer ellipse.

Background Information

The principles of Newton's Law of Gravitation and Kepler's Laws of Planetary Motion are involved in the determination of the orbits of satellites and the trajectories of space probes. The path a space vehicle follows as it is launched may be an ellipse, a circle, a hyperbola, or a parabola, depending upon a number of factors including velocity, altitude and direction of injection.

When the velocity of the spacecraft at launch is sufficient (about 8 kilometers or 5 miles per second) the spacecraft will continue to move forward in space so rapidly that the distance it falls toward the center of the earth in one second (about 4.9 meters or 16 feet) will match the amount the earth's curvature causes the earth's surface to recede from under the spacecraft. If there is an exact balance between inertial speed and the centripetal force exerted by gravity, the spacecraft will follow a circular orbit. If the velocity of the craft is greater, the vehicle will leave the earth in an elliptical orbit whose eccentricity will depend upon the ratio of the velocity to the force of gravity. Likewise, lesser velocities will cause the vehicle to follow a parabolic trajectory and eventually fall to the earth's surface.

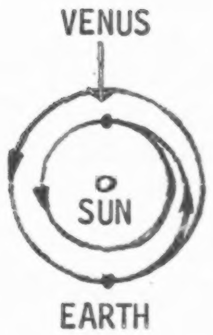
As distance from the earth increases, the centripetal force of gravity decreases. As a result, the velocity needed to counterbalance the pull of gravity and keep a satellite in a circular orbit becomes less with increasing altitude. Of special interest is the distance of 35,880 kilometers or 22,300 miles from the surface of the earth. At this distance, with a velocity which counterbalances the earth's gravity, a satellite, traveling in the earth's equatorial plane and in the same direction as the earth's rotation, will remain stationary above a point upon the earth's surface.

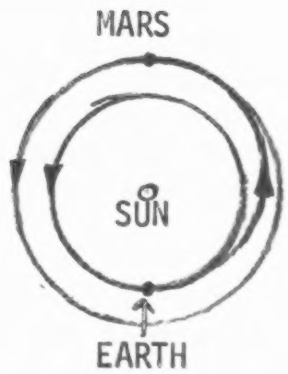
When velocity and altitude are the same, the orbital period will be the same; however, the direction of injection will affect the shape of the orbit. At a velocity which, with horizontal injection, would result in a circular orbit, injection which varies from the horizontal will result in an ellipse whose eccentricity depends upon the angle of injection -- eccentricity becoming greater as the injection angle approaches the vertical.

When perigee velocity increases sufficiently to result in an orbital eccentricity of 1, the orbital path changes from an ellipse to a parabola and the orbiting body leaves its primary. At this velocity, called escape velocity, a satellite leaves the earth and becomes a space probe. As the spacecraft travels farther from the surface of the earth, the influence of the earth's gravitational force decreases; however, as the spacecraft comes closer to other members of the solar system, the influence of their gravitational forces increases. The gravitational attraction of the nearest solar body becomes the dominant force in controlling the path of the space probe.

The velocity needed to escape the gravitational attraction of the earth decreases with altitude and is independent of the method used to arrive at that altitude. Frequently, staging is used to boost space probes to an altitude where less power is required to accelerate the probe to escape velocity. The exact trajectory of a space probe can be determined only if the interaction of the gravitational fields of all the various solar members involved is calculated. This is an exercise in celestial mechanics which requires highly complicated mathematical computations and is usually calculated by a properly programmed computer.

A minimum energy trajectory, for changing from an Earth orbit to an orbit around another planet or from one orbital path to another orbital path around Earth, is known as a Hohmann transfer ellipse or a Hohmann orbit. This trajectory is one in which the spacecraft leaves its old orbit at a tangent and enters the new orbit from a tangential direction. (See drawing.) Such a trajectory is not always feasible because of the time which may elapse between periods when the planets are positioned correctly to allow for such a transfer. If the launch cannot be planned to take advantage of the optimum transfer trajectory, some of the available energy must be used to accelerate the vehicle to the velocity necessary to make the transfer.





Activities

1. Demonstrate the way in which the shape of an orbit is influenced by the velocity of the satellite and the gravitational pull of its primary.

   Materials needed

   String
   Strong magnet
   Iron weight

   Suspend the iron weight on a length of string directly over the magnet. Start the weight moving in a circular path and observe the effect of the magnet's attraction upon the shape of the orbit. Vary the velocity and the initial angle of motion and observe the differences in the orbits.

2. Demonstrate the effect of gravity on the path of a moving object.

   (a) Materials needed

   Table
   Wet tennis ball

   Roll the wet tennis ball off the end of the table several times at different speeds. The moisture in the ball will mark the spot where it first bounces. Notice the effect of an increase in velocity upon the distance the ball travels horizontally.

   (b) Materials needed

   Steel ball (ball bearing)
   Strong magnet

   Place the magnet on a table. Roll the ball past the magnet several times. Vary speed and vary the distance away from the magnet. Observe the effect of the magnet upon the path of the ball.

CENTRIPETAL FORCE

Objective

To gain facility in calculating the amount of centripetal force in pounds.

Background Information

A satellite is held in orbital position by the pull of gravity, or the centripetal force, exerted by the body around which it circles. The following formula may be used to determine the amount of centripetal force in pounds:

$F = m \frac{v^2}{r}$, where F = centripetal force in pounds,

m = mass (weight divided by 32.2 feet per second per second)

v = velocity in feet per second,

r = radius in feet.

Activities

1. An object weighing 12 ounces is whirled with a velocity of 12 feet per second at the end of a three-foot string. What is the tension in the string (to the nearest ounce)?
2. An Earth satellite weighing 10 pounds is orbiting with a velocity of 1.5 miles per second at a radius of 100 miles from the surface of the earth. Find the centripetal force which is holding it in orbit.

Answers

1. 18 oz.
2. 3.7 lb.

ECCENTRICITY OF AN ELLIPSE

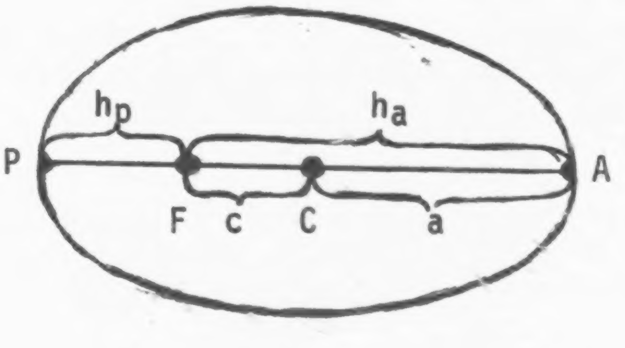
Objective

To gain facility in calculating the amount of the eccentricity of an ellipse.

Background Information

Johannes Kepler (1571-1630), using observations and mathematical calculations, showed that the orbits of the planets were ellipses rather than circles, as had been believed prior to his calculations. An ellipse is a simple closed curve generated by the movement of a point whose distance from two fixed points (foci) is a constant sum. Eccentricity (e) is a term used to describe the shape of the ellipse and indicates the ratio of the distance of one of the foci from the center (c) to the distance to the point farthest from the center (a). When this ratio is zero, the figure is a circle. When the ratio is one, the figure is no longer an ellipse but is parabolic.

The eccentricity of the orbit of artificial satellites is of great concern to the scientists launching them. The amount of eccentricity desired can vary from zero, as would be the case for the weather satellites such as TIROS, to near one, as in the case of deep space probes such as Explorer XIV.



The formula for the eccentricity of an ellipse is as follows:

$e = \frac{c}{a}$,

where (e) is the eccentricity of the ellipse; (c) is the distance from the focus to the center and is equal to 1/2 $(h_a - h_p)$ with (h_a) the aphelion distance and (h_p) the perihelion distance; and (a) is the length of the semi-major axis and is equal to 1/2 $(h_a + h_p)$ with (h_a) the aphelion distance and (h_p) the perhelion distance.

Activities

1. Complete the following table by calculating the eccentricity of the orbit of each satellite listed.

Satellite	Apogee Distance	Perigee Distance	Eccentricity
Sputnik I	588 mi.	141 mi.	
Sputnik II	1038	140	
Explorer I	1584	224	
Vanguard I	2462	405	
Telstar II	6713	604	

2. Calculate to three decimal places the eccentricity of the orbit of Explorer VI if its perigee distance were 157 miles and its apogee distance were 26,357 miles.

3. Pioneer V was designed and launched into an orbit around our sun to investigate interplanetary space. If the perihelion distance of Pioneer V were 74.9 million miles and its aphelion distance were 92.3 million miles, calculate the eccentricity of its orbit to three decimal places.

4. Calculate to three decimal places the eccentricity of the orbit of TIROS II if its perigee and apogee distances of 387 and 452 miles respectively.

5. The Orbiting Solar Observatory, OSO I, was launched in March, 1962 into an orbit with perigee and apogee distances of 343.5 and 369.8 miles, respectively. Calculate the eccentricity of its orbit to three decimal places.

6. If the orbit of Syncom II has perigee and apogee distances of 22,062 and 22,750 miles respectively, calculate to five decimal places the eccentricity of its orbit, and round off to four decimal places.

7. Gemini VIII, in which the first docking maneuver was accomplished, had an apogee and perigee at approximately 169 miles and 100 miles respectively. Find the eccentricity of the orbit.

Answers

1. S I, 0.051; S II, 0.098; E I, 0.139; V I, 0.189; T II, 0.399
2. e = 0.759
3. 0.104
4. e = 0.007
5. 0.003
6. 0.01302 or 0.0130
7. 0.008

CONVERSION OF SPEED AND VELOCITY

Objective

To gain facility in converting figures indicating speed and velocity from one measurement system to another.

Background Information

Because units of measurement are arbitrary and it is frequently more convenient to use one measurement system than another, it is important to be able to convert from one system to another quickly. Below is a table for use in converting speed and velocity from one system to another.

Conversion factors for speed and velocity.

Velocity	ft/sec	Km/hr	mi/hr
1 ft/sec =	1	1.0973	0.6818
1 Km/hr =	0.9113	1	0.6214
1 mi/hr =	1.4667	1.6093	1

Activities

1. Escape velocity from Earth is approximately 7 miles per second. What is the escape velocity in feet per second? What is it in miles per hour? (to nearest thousand)

2. Escape velocity from Jupiter is 37 miles per second. What is the escape velocity in miles per hour?

3. Escape velocity from the moon is 5400 miles per hour. What is the escape velocity in miles per second?

4. If an object has a parabolic orbit, with the sun at the focal point of the orbit, it means that it is traveling with a speed in excess of 616 kilometers per second. What is the velocity of the object in

   (a) miles per second (c) miles per hour?
   (b) kilometers per hours?

5. Vanguard III had a perigee velocity of approximately 29,820 kilometers per hour and apogee velocity of approximately 20,349 kilometers per hour. What was Vanguard III's average orbital velocity in kilometers per second?

6. If Vanguard III were traveling at a velocity of approximately 18,522 miles per hour at perigee, what is its velocity in

   (a) miles per minute?
   (b) miles per second?
   (c) kilometers per second?

Answers

1. 36,960 per second; 25,200 mph
2. 133,200 mph
3. 1.5 mi per sec
4. (a) 381.92
   (b) 2,217,600
   (c) 1,374,912
5. 6.9
6. (a) 308.7
   (b) 5.1
   (c) 8.2

SPEED

Objective

To gain facility in using the formula $v = \frac{\Delta s}{\Delta t}$ to calculate speed when distance and time elapsed are given.

Background Information

It was many centuries before man was able to prove that Earth was moving in space. Now we know that members of our solar system, as well as the other bodies in space, including artificial satellites, move in relationship to one another.

An object that moves without changing speed is said to be in uniform motion. The orbits of the planets are elliptical, so the speed of each planet varies according to its position in its orbit. However, it is often customary to treat the orbits as perfect circles (circumference = π x diameter) and the speed of the planet as being uniform.

The following formula may be used to find the speed of an object which is moving at a uniform rate.

$v = \frac{\Delta s}{\Delta t}$, where v = the speed,

Δs = the total distance traveled,

Δt = the time elapsed

Activities

1. The moon travels approximately 1,500,000 miles in its 28-day orbit of Earth. Assuming the orbit of the moon to be circular and its speed to be uniform, what is its approximate (nearest thousand) speed in

   (a) miles per day? (b) miles per hour?

2. TIROS I has an orbit of about 28,000 miles, which it completes every 99 minutes. Estimate its average speed to the nearest ten miles per minute.

3. Echo I has an approximately circular orbit about 1,000 miles above Earth, and it has been timed at 118.3 minutes for one revolution. What is its speed (to nearest mile per minute)? (Remember the earth's radius is about 4,000 miles.)

4. The Alouette program is an example of the cooperative effort between governments to expand man's knowledge of space. Canadian scientists designed and built the 320-pound satellite called Alouette; NASA launched it from the Pacific Missile Range. Alouette's orbit is nearly circular at about 630 miles altitude. The time of revolution is 105.4 minutes. What is Alouette's speed? How does the speed of Alouette compare with that of Echo I?

5. If a particular satellite traveled 30,000 miles in 6 seconds, what would the velocity of that satellite be in miles per second?

6. What is the diameter of the Milky Way in light years if an object with a velocity of 0.484 the speed of light must travel 206,612 years to cross our galaxy?

7. In the near future, man may venture a trip to the closest visible star, Alpha Centauri. If the space vehicle could travel at 0.43 speed of light, and the trip took 10 years, how far away is Alpha Centauri?

8. If a satellite were launched into a near circular orbit 35,400 kilometers from the earth and had a velocity of 10,950 kilometers per hour, what distance in kilometers would be covered in one orbit if the period of revolution was 23.3 hours?

9. If light travels 93 million miles from the sun to the earth (1 A.U.) and has a velocity of about 186,000 miles per second, how long does it take for the light to get from the sun to the earth?

10. How long (to nearest second) does it take light to travel from the sun to the planet Saturn ? (Saturn is approximately 892,000,000 miles from the sun.)

11. What distance in miles does the earth travel in its orbit in one day? (Earth is approximately 93,000,000 miles from the sun.)

12. The circumference of the earth at the equator is approximately 25,000 miles. If the earth rotates once in 24 hours, how fast is it rotating at the equator (to nearest mile)?

13. The moon's diameter is approximately 2,200 miles. It makes approximately one rotation on its axis every twenty-eight days. What is the speed (mph) of the moon's rotation at its equator?

14. Syncom II, a synchronous-orbit satellite, has a mean distance of about 22,300 miles above the earth's surface. It revolves once in twenty-four hours. What is its orbital velocity?

15. A space probe leaves Earth at a speed of 25,000 miles per hour. How many days will be required for the spacecraft to reach Jupiter when Jupiter is closest to Earth (393,000,000 miles, approximately)?

16. Traveling 25,000 miles per hour, a manned spacecraft leaves Earth for Neptune. How many days will it take to reach Neptune when Neptune is closest to Earth (2,707,000,000 miles, approximately)? How many years would this be? If the crew remains on Neptune for 193 days and then returns to Earth, how many years would the entire trip take? (Assume 365 days per year.)

17. If a satellite, traveling 500 miles above the earth at 18,000 mph, completes a circular orbit in 90 minutes, how long will it take a space capsule traveling 300 miles above the earth at 18,960 mph, to complete one orbit? Assume the earth's radius to be 4,000 miles, and use the fact that a satellite's orbital period in hours varies directly as the radius of its orbit and inversely as its orbital velocity.

Answers

1. 54,000; 2,000
2. 280 mi./min.
3. 266 mi./min.
4. 276 mi./min.; 1.04:1
5. 5,000 mi./sec.
6. 100,000 light years
7. 4.3 light years
8. 255,135 km
9. 500 sec = 8 1/3 min.
10. 4,796 sec. = 80 min.
11. 1,601,566 mi.
12. 1,042 mph
13. 10.3 mph
14. 6,888 mph
15. 655 days
16. 4,512 days; 12.3 years; 25 years
17. approximately 82 min.

VECTOR REPRESENTATIONS

Objective

To gain facility in drawing vector representations.

Background Information

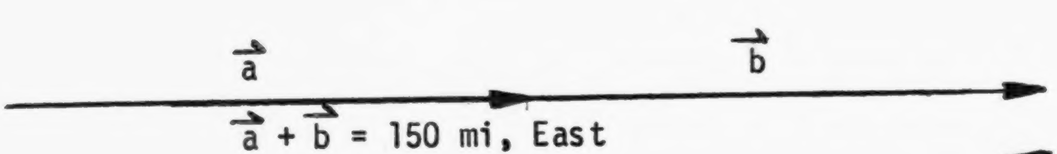
Distance, a measurement of length, is a scalar quantity. Distance in association with a specific direction can be represented by a vector, which has both magnitude and direction (including an indication of direction, such as east or west along the line). Speed (rate) is a scalar quantity, but speed in association with a specific direction is a vector quantity, called velocity, and can be represented by a directed line segment.

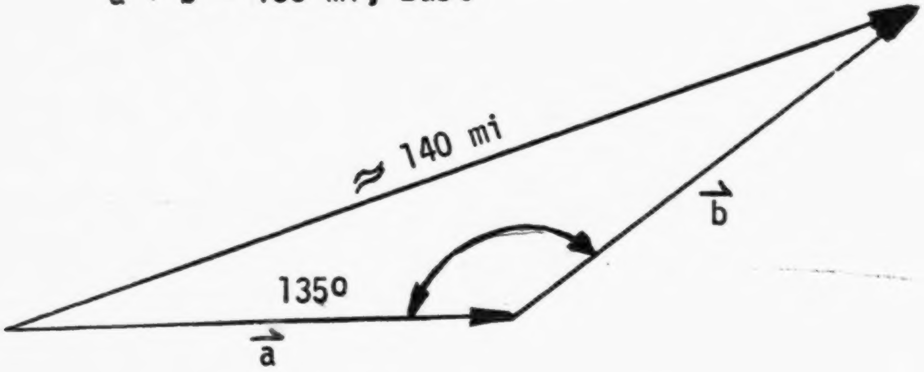
Activities

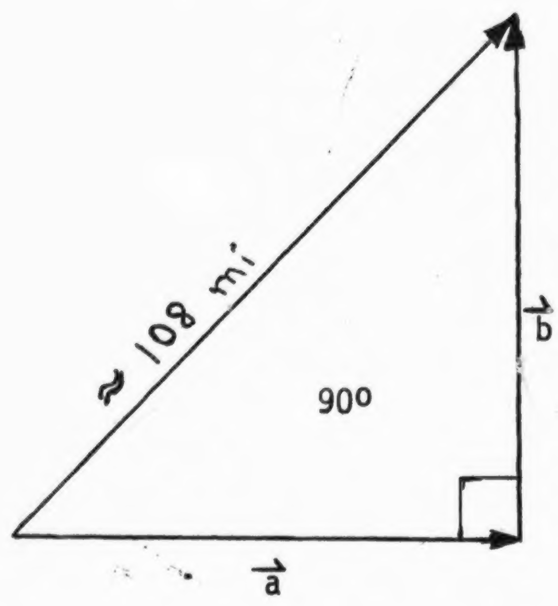
Make vector representations of the following situations. For each flight determine the distance of the terminal point from the starting point.

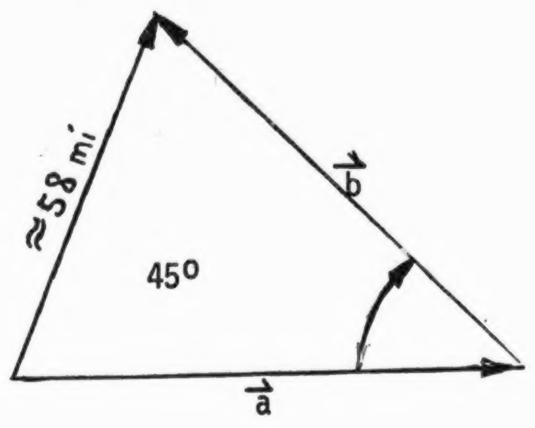
1. Pilot A flys 75 miles due east and then 75 miles due east.
2. Pilot B flys 75 miles due east and then 75 miles NE.
3. Pilot C flys 75 miles due east and then 75 miles north.
4. Pilot D flys 75 miles due east and then 75 miles NW.
5. Pilot E flys 75 miles due east and then 75 miles west.

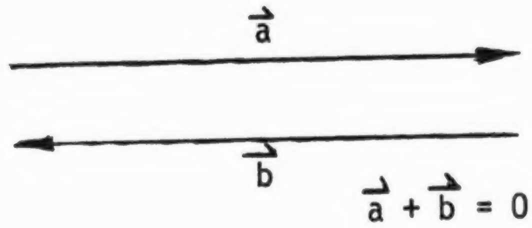
Answers











$\vec{a} + \vec{b} = 0$

SCALE: 1/32" = one mile
3/16" = 10 miles

VELOCITY

Objective

To gain facility in drawing vector representations to determine the composition of velocities.

Background Information

A displacement has magnitude (distance) and direction. Therefore we represent displacements by vectors. The result of two successive displacements is a vector quantity; any change in (difference of) displacements is a vector quantity.

The rate (of speed) at which an object travels has been defined as the change in distance per unit of time. Thus rate is represented by a scalar; it has magnitude but not direction. We can associate a direction with a rate by considering displacement instead of distance.

In order to determine how much he must turn his aircraft into the wind (crab), a pilot must be able to solve problems similar to the one which follows.

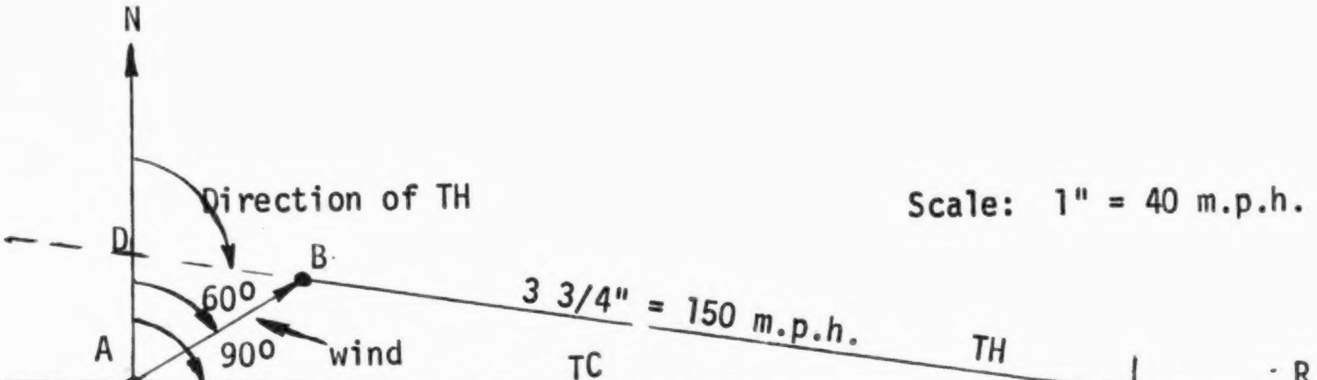
Example: A pilot, whose aircraft's average speed is 150 mph, wishes to maintain a true course (TC), of 90°. He encounters a wind blowing from 240° (toward 60°) at 40 mph.

(a) In what direction must he head (turn) his aircraft in order to fly his intended course?

(b) What is his resultant speed over the ground?

To make a vector representation of this problem follow the steps given below.

I. Draw a line to represent north and mark a point "A", on this line.



II. Draw a long line through Point A to represent the direction of the intended course, $\overrightarrow{AR}$, at 90°. This is the direction of the resultant.

III. Select a convenient unit and draw the wind vector $\overrightarrow{AB}$. (1" = 40 mph)

IV. From B measure a vector 3 3/4" long to represent 150 mph so that the end touches Line $\overline{AR}$ at Point C.

V. What is the direction of Line $\overrightarrow{BC}$? Measure for this direction (true heading, TH) at Point D in the diagram.

VI. How long is Segment $\overline{AC}$? How many mph does this length represent? This speed is the rate the plane is traveling along the desired course.

The pilot must head his aircraft in a direction of 98° (crab to the right). The resultant speed will be approximately 180 mph (4 1/2") due to the wind encountered (a tailwind).

Activities

1. A pilot wishes to travel a true course (TC) of 60°. The average speed of his aircraft is 120 mph. He encounters wind of 40 mph blowing from a direction of 280°. In what direction must he head his aircraft (TH) in order to fly the desired course? What is his speed over the ground?

2. The desired course (TC) is 40°. If the average speed of the aircraft is 160 mph and a wind from the east, 90°, is blowing at 25 mph, what heading (TH) is necessary to maintain the TC? What is the airplanes speed over the ground?

3. At a certain instant in its upward flight a sounding rocket has a velocity of 2000 ft/sec at 0° to the azimuth. At this instant the rocket enters upper air currents which have a velocity of 200 ft/sec, and are moving from west to east. What is the true velocity of the rocket?

4. At a point in its path, a rocket which is falling to Earth has a speed of 3000 ft/sec and a flight path angle of 60° to a horizontal line. What are the horizontal and vertical (x and y) components of the velocity?

Answers

1. 48°; 150 mph, approximately
2. 48°; 143 approximately
3. 2010 ft/sec.
4. $V_x = 1.5 \times 10^3$ ft/sec; $V_y = 2.59 \times 10^3$ ft/sec.

MACH NUMBER

Objective

To gain facility in converting speed, expressed as distance per unit of time, to Mach number and vice versa.

Background Information

The term Mach number honors Ernst Mach, an Austrian physicists, who made valuable contributions to the study of supersonic flight. Mach number indicates the ratio of the speed of a moving body to the speed at which sound travels through the air (at sea level, usually considered to be approximately 1100 feet per second or 750 miles per hour). Because the speed of sound varies depending on atmospheric conditions, a Mach number can represent different actual speeds. Speeds greater than Mach 1 are called supersonic speeds; less than Mach 1, subsonic.

Activities

1. What is the Mach number of an airplane flying at 1,100 feet per second?

2. If an airplane flies at nine-tenths the speed of sound, what is its mach number?

3. The F-111 has a speed of Mach 2.5. Express this speed in miles per hour.

4. The X-15 can travel at a speed of 4,000 miles per hour. Express this speed as a Mach number.

5. If an airplane is traveling at a speed of Mach 1.5, how fast is it traveling in nautical miles per hour? How fast is it traveling in statute miles per hour?

Answers

1. 1
2. 0.9
3. 1,875
4. 5.3
5. 978.75; 1,125

FALLING BODIES

Objective

To gain facility in calculating the acceleration rate of falling bodies.

Background Information

The moment an aircraft or any other moving object increases or decreases its velocity, it undergoes acceleration or deceleration. An airplane accelerates during takeoff, cruises at a certain velocity in a given direction, and then decelerates during landing. Deceleration is sometimes called negative acceleration. Freely falling objects are accelerated by the pull of gravity. To find the acceleration of a freely falling object, the formula $s = 1/2\ gt^2$ could be used. The letter (s) refers to the distance, (g) the acceleration, and (t) the time.

Example: If a ball is dropped from a building 256 feet high, it takes 4.0 seconds to reach the ground. What is the acceleration due to gravity?

Solving the formula for g, we find

$$g = \frac{2s}{t^2} = \frac{2 \times 256}{(4)^2} = 32 \text{ feet per second per second } (\text{ft/sec}^2).$$

The object is accelerating 32 feet per second every second that it falls.

Activities

1. Knowing the acceleration due to gravity, calculate the distance the ball in the above example falls by the end of each second. (This information might be shown on a graph.)
2. How long will it take an object to fall 1,024 feet?
3. Find the impact velocity in feet per second of a model rocket which was launched to a height of 2000 feet in three seconds.
4. Find the impact velocity in meters per second of a spent booster dropped at an altitude of 1 kilometer.
5. How long will it take for a rocket with zero velocity at 2,000 feet to fall back to earth?

6. If the first booster on a launch vehicle burns for 8 seconds, is separated from the launch vehicle, and then starts descending from an altitude of 1 kilometer, how long will it take for the spent booster to splash into the ocean? (32 ft/sec^2 9.8 m/sec^2)

7. A spacecraft is two miles above the earth's surface. Assuming no wind resistance, calculate the length of time it will take the spacecraft to reach the ground.

8. A spacecraft is 7,000 feet above the earth's surface. Assuming no wind resistance, calculate the length of time it will take the spacecraft to reach the ground.

9. A spacecraft begins to fall, and 12 seconds later it reaches the ground. How far above the earth (in feet) was it when it began to fall?

10. When a body is dropped, it falls with the acceleration of gravity independent of any horizontal velocity which the body may be given. A bombing plane flying at an altitude of 30,000 feet with a speed of 500 miles per hour drops a bomb. How long will it take the bomb to reach the ground? How far horizontally will the plane travel during this interval?

11. A sky diver left his plane at 12,000 ft. and fell freely to an altitude of 3,000 ft., where he opened his parachute. Determine the time in seconds (t) that he fell before opening his chute, if the distance in feet (d) fallen in free flight equals $16\ t^2$.

Answers

1. When $t = 1$, $d = 16$ ft.; when $t = 2$, $d = 64$ ft.
   when $t = 3$, $d = 144$ ft.; when $t = 4$, $d = 256$ ft.
2. 8 sec.
3. 358.4 ft/sec.
4. 140.14 m/sec.
5. 11.2 sec.
6. 14.3 sec.
7. 25.7
8. 20.9
9. 2,304 feet
10. 43.3 sec.; 733 ft.
11. 23.7 sec.

G-FORCE

Objective

To learn how to calculate increased stress due to acceleration.

Background Information

Acceleration due to the pull of gravity gives a body on the surface of the earth its normal weight. A force equal to the acceleration of gravity is called "one g". Increased acceleration will have the effect of increasing the "weight" of the body or the g-force which affects the body. Humans can, for brief periods, withstand the stress of acceleration up to twenty times the acceleration due to the pull of gravity. The following formula may be used to find the amount of stress objects may be subjected to when undergoing acceleration.

$$F = wa/g$$

where F = G-force in pounds,

w = weight in pounds,

a = acceleration in feet per second per second,

and g = gravity (32.2 feet per second per second).

Activities

1. A manned spacecraft takes off and gains speed at the rate of 24 feet per second per second for 58 seconds. If a man weighing 160 pounds is standing on a spring scale in the spacecraft, what will the scale read during the first 58 seconds of flight?
2. A manned spacecraft takes off and gains speed at the rate of 8 feet per second per second for 80 seconds. After this 80 seconds, it continues to rise at the rate of 20 feet per second. If a man weighing 180 pounds is standing on a spring scale in the spacecraft, what will the scale read during the first 80 seconds? After the first 80 seconds?
3. An astronaut weighing 170 pounds is subjected to 21.7 G's on takeoff. What is the acceleration of the spacecraft at takeoff (in feet per second per second)?

Answers

1. 279 lbs. 2. 225 lbs; 292 lb. 3. 4.11 ft/sec.^{2}

GRAVITATIONAL ACCELERATION

Objective

To gain facility in calculating velocity of objects undergoing vertical acceleration or deceleration.

Background Information

Suppose a ball were thrown vertically to a height of 100 feet. On its way up the ball would decelerate until it reached its maximum height, where it would momentarily stop (Velocity at this point is equal to zero.) before beginning its fall to the ground. When an object coasts upward after being propelled, deceleration due to gravity is -32 feet per second per second (ft/sec^2).

To find the velocity of an object which has been propelled upward, use the following formula: $a = \frac{v - v_0}{t}$, where (a) is the acceleration due to gravity, (v) is the final velocity, (v_0) is the initial velocity, and (t) is the time.

Example: If an arrow is shot vertically to a height of 196 feet, (a) what is the time required for the upward flight, (b) what is the time interval between the shooting of the arrow and the arrow's striking the ground, (c) what is the velocity of the arrow when it leaves the bow, and (d) what is the velocity of the arrow when it strikes the ground?

(a) $s = 1/2\ gt^2,\ t^2 = \frac{2s}{g} = \frac{2 \times 196}{32} = 12.25,\ t = 3.5$ sec.

(b) time up = time down, therefore total time (t) = 3.5 x 2 = 7 sec.

(c) $a = \frac{v - v_0}{t},\ v - v_0 = at$

$0 - v_0 = -32 \times 3.5$

$- v_0 = -112$ ft/sec^2

$v_0 = 112$ ft/sec^2

(d) $v - v_0 = at,\ v - 0 = 32 \times 3.5 = 112.0$ ft/sec^2

Activities

1. An object is thrown vertically to a height of 78.4 meters in 4 seconds. Calculate the acceleration due to Earth's gravity in

   (a) centimeters per second^2, and
   (b) meters per second^2.

2. A model rocket is launched to a height of 2,000 feet in three seconds. Calculate the approximate acceleration of the rocket.

3. Suppose you were on the moon where the acceleration due to gravity is 1.67 meters per second^2 and you shot an arrow with an initial vertical velocity of 33.6 meters per second^2,

   (a) what would be the time of the entire flight of the arrow, and
   (b) how high would the arrow soar?

4. If an object is propelled vertically from the surface of our sun to a height of 2,195 meters, it will land 8 seconds later. Calculate the acceleration due to the sun's gravity and compare it to that of the moon and of the earth.

5. A rocket accelerates at 20 feet per second per second for 10 seconds. How high does it go?

6. A second rocket accelerates at 35 feet per second per second for 7 seconds. How much higher or lower does it go than the first rocket?

7. A rocket accelerates at 25 feet per second per second and reaches an altitude of 7,500 feet. How long did it accelerate to reach this height?

Answers

1. 980 cm/sec^2; 9.8 m/sec^2

2. 444.4 ft/sec^2

3. t = 40.24 sec; d = 338 meters

4. 274.4 m/sec^2; 28:1; 164:1

5. 1,000 feet

6. 857.5; lower by 142.5 ft.

7. 24.5

WEIGHT ABOVE THE EARTH

Objective

To gain facility in determining the apparent weight of an object which is at a distance above the surface of the earth.

Background Information

The pull of gravity decreases as an object moves away from the surface of the earth. The weight of an object when it is at a distance above the surface of the earth may be found by using the following formula:

$W_h = \left(\frac{r}{r+h}\right)^2 w_s$, where W_h = weight of object at a distance above the surface of the earth,

r = radius of the earth (3,960 miles),

h = height above the surface of the earth,

and w_s = weight of body on earth.

Activities

1. A spacecraft weighing two tons at the surface of the earth is 200 miles above the surface. What is its weight at that altitude (to nearest pound)?
2. The Apollo spacecraft weighs about 48 tons at takeoff. How much does it weigh when it is 3,960 miles from the earth?
3. The command module of the Apollo spacecraft weighs about six tons at takeoff. How much does it weigh when it is 1000 miles from the earth's surface?
4. One of the earliest satellites put into orbit weighed only 6 pounds at takeoff. When in orbit it had a weight of 5.6 pounds. What was its height above the earth's surface, to the nearest ten miles?

Answers

1. 3610
2. 12 tons
3. 7489
4. 165 miles

Resource Materials

Books

Ahrendt, Myrl H., The Mathematics of Space Exploration. pp. 11-25, 83-108. Motion, mass, weight, gravity, orbital paths.

Bennett, Clarence E., Physics Without Mathematics. Review of basic laws of force and motion.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 41-82. Space orbits and trajectories.

Lundquist, Charles A., The Physics and Astronomy of Space Sciences. pp. 16-20. Earth's gravitation field.

Ovenden, Michael W., Artificial Satellites. pp. 31-39 Principles involved in determining the orbit of a satellite.

Sutton, Richard M., The Physics of Space. pp. 47-57, 92-122. Kepler's laws; law of gravitation; satellite orbits; weightlessness.

Wilson, Mitchell, Seesaws to Cosmic Rays. pp. 11-26. Balance of forces; motion.

Films

Basic Physical Science: What is Uniform Motion? (b/w, 13 min.)

Centripetal Force and Satellite Orbits (c, 11 min.)

Elliptical Orbits (b/w, 19 min.)

Free Fall and Projectile Motion (b/w, 27 min.)

Free Fall in Space (c, 4 min.)

Gravity, Weight, and Weightlessness (c or b/w, 11 min.)

Satellite Orbits (c, 20 min.) Electronic planetarium used to demonstrate orbits.

Space Orbits (c, 18 min.) Orbital patterns and forces producing them.

Universal Gravitation (c, 31 min.)

HEAT AND HEAT ENGINES

Heat is the energy produced by the motion of the molecules of matter. The greater the speed of movement, the higher the heat level of the material. Any action or reaction which will increase the motion of the molecules will increase the level of the heat. Conversion of heat energy to kinetic energy in the rocket booster provides thrust to put the spacecraft into orbit.

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AERODYNAMIC HEATING

Objective

To be able to explain why a blunt body is the ideal shape for a spacecraft reentering the earth's atmosphere.

Background Information

Aerodynamic heating, which occurs in high speed flight, is a result of (1) the kinetic energy of the air being changed to heat and (2) the transfer, by convection, of some of this heat to the body as the hot air passes over it. A very thin layer of air, called the boundary layer, outside the surface of the body provides the mechanism for decelerating air flow and for transferring the heat which results from this deceleration.

The temperature of the ambient air is the air temperature produced by random motion of molecules. The forward motion of the reentering spacecraft, added to the random motion of the molecules, significantly increases the temperature of the air. Stagnation temperature, the air temperature reached as a result of forward motion, is dependent upon the spacecraft's velocity and is related to the ambient air temperature as follows:

$T_S/T_O = 1 + .2M^2$, where T_S is the stagnation temperature, T_O is the ambient air temperature, and M is the Mach number of the moving vehicle.

As molecules of air become increasingly hot, their motion becomes faster, until the air temperature reaches the point where the molecules absorb some of the heat energy by excitation of individual parts of the molecules. At sufficiently high temperatures, the molecule itself may break down into its atomic components and the atoms may lose their outer ring electrons.

A blunt body is the ideal shape for a spacecraft reentering the earth's atmosphere because (1) less of the forebody of the craft is exposed to the area of intense heating; (2) a greater drag coefficient causes deceleration of the craft at higher altitudes where air density is lower; (3) pushing a strong shock wave ahead of it, dissipates almost all of its kinetic energy; and (4) little heat is absorbed into the boundary layer and little is transferred to the surface.

A pointed body is preceded by a weak shock wave while a blunt body is preceded by a strong shock wave in which nearly all of the velocity of the moving body is added to the random velocity of the molecules and the molecules in the boundary layer move at a high velocity. A slight curvature of the frontal surface causes nearly even heating across the entire frontal surface of the craft.

Activity

Demonstrate the effect of differences in the shapes of spacecraft.

Materials needed

- Balsa spacecraft models of various shapes
- Tub or large pan
- Water

Float the spacecraft, one at a time, in the water. Observe the differences in the ripple patterns as the different craft are moved forward in the water.

HEAT TRANSFER

Objective

To be able to describe (1) the methods used to protect the reentering spacecraft against excessive heat and (2) the methods used to cool the astronaut's space suit.

Background Information

Protection against excessive heat can be provided by (1) a covering with enough thermal capacity to soak up the heat without melting or damaging the structure; (2) a covering with the capability to radiate the major portion of the heat away as rapidly as it accumulates; or (3) a covering of ablative material which blocks the transfer of heat from the boundary layer, soaks up some of the heat, and radiates the remainder.

Beryllium, the best material to use when high thermal capacity is desired, is used where excessive heating is of relatively short duration. Heating of long duration, but at lower levels, can best be withstood by heat-resisting nonmetallic ceramic materials or refractory alloys or metals. Ablative materials, however, often are the most practical protection because they can withstand high heat for prolonged periods of time.

Ablative materials are usually a mixture of glass or quartz fibers for strength, micro-balloons to reduce density, and a type of polymer for a binder. Heating causes the polymer to char, thus absorbing heat, and to release gases which form a blanket between the surface of the craft and the boundary layer, thus reducing the boundary layer's capability to transfer heat to the surface. The carbonaceous material left as a result of the charring is an effective radiator of most of the remaining heat. The glass or quartz fibers also melt and vaporize, thus assisting in the ablative action. The micro-balloons, hollow spheres of plastic or glass, act to reduce the density of the ablative material thereby reducing heat conductivity. A reduction in heat conduction is important because the adhesive used to bond the ablative material to the nose of the craft cannot withstand the levels of heat that the ablative material itself can withstand.

Radiation from the sun and heating caused by the expenditure of energy by the astronaut make some kind of space suit cooling system essential. Circulating oxygen cooled the space suit used on the Mercury flights. However, the circulation of oxygen at the pressure of 3.5 psi is not rapid enough to cool a suit when the astronaut is expending as much energy as he will be when he is on the surface of the moon. The Apollo suit has been developed with a cooling system of circulating water. A network of small plastic tubes in the undergarment of the suit conducts heat from the body to be cooled by the circulating water which, in turn, is cooled by a heat exchanger in the life support system. Because gas does not cool effectively by convection, water cooling has an additional advantage in that it reduces the perspiration rate necessary for comfortable cooling.

Activities

1. Demonstrate the difference in the ability of various metals to withstand heat.

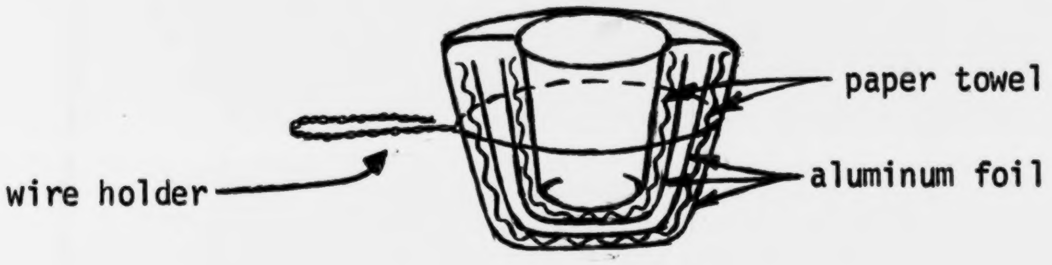
   Direct the flame of a blow torch or bunsen burner on to the surface of different metals, record the length of time it takes for them to become "cherry red", and inspect the surface of the metal after cooling to detect deterioration caused by excessive heat.

2. Demonstrate how layers of materials can be used to insulate the astronauts against the heat of reentry.

   Materials needed

   Paper cup (6 to 8 oz.)
   Paper towels
   Aluminum foil
   Coat hanger wire
   Thermometer
   Masking tape
   Bunsen burner

   Crumple a paper towel around the outside of the paper cup. Add two layers of aluminum foil and another loosely crumpled towel. Add a final covering of aluminum foil and tape it securely to the top edge of the cup. Make a holder of the coat hanger wire. Place two ounces of water in the cup. Record the temperature of the water and then place the covered cup in the flame of the burner for one minute. Record the water temperature again. If the cup is properly insulated, the temperature of the water will not rise more than 2° Fahrenheit.

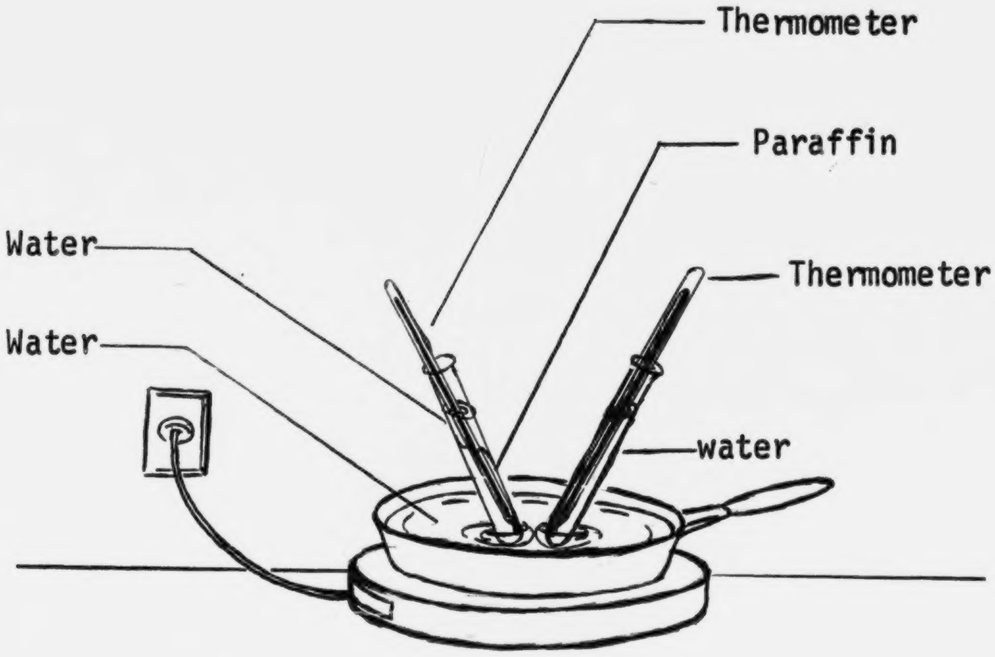


3. Demonstrate the cooling effect of ablation material.

Materials needed

- Hot plate
- Pan to hold water as it is heated
- 2 test tubes
- 2 thermometers
- Paraffin

Coat one test tube with a thick layer of melted paraffin. Place a thermometer in each test tube, and suspend the test tubes in water in the pan. (See illustration.) Heat the water and notice the difference in the rate of change in the temperature readings as the water level rises.


Thermometer
Paraffin
Water
Thermometer
Water
water

TEMPERATURE CONVERSION

Objective

To gain facility in converting readings on one temperature scale to another scale.

Background Information

As its temperature is lowered, a gas decreases in volume and pressure. Theoretically, the temperature might reach a point where the gas would have essentially disappeared, with no volume and no pressure. This temperature is known as absolute zero or zero degrees Kelvin (named after one of the originators of the idea). The absolute temperature scale is recorded in degrees Kelvin (°K).

There are two other temperature scales as well--centigrade or Celsius, °C, and Fahrenheit, °F. There is no difference in the size of the interval used to indicate a degree on the Celsius and absolute scales. This means that on both scales there is the same number of degrees, for instance, between the freezing point and the boiling point of water. The absolute scale temperature of 273° K is equal to 0° on the Celsius scale.

There is a difference in the size of the interval used to indicate a degree between the Celsius scale and the Fahrenheit scale. Five degrees on the Celsius scale is equal to 9° on the Fahrenheit scale.

Formulas for converting temperature readings from one temperature scale to another follow

$$°K = °C - 273°$$

$$°C = °K + 273°$$

$$°C = \frac{(F° + 40°)}{1.8} - 40°$$

or

$$°C = (°F - 32°) \times 5/9$$

$$°F = (C° + 40°)\ 1.8 - 40°$$

or

$$°F = 9/5\ °C + 32°$$

Activities

1. At 25 km. above the earth, the atmospheric temperature is approximately 215° K. What is that temperature as expressed in Celsius degrees? In Fahrenheit degrees?

2. At 50 km. above the earth, the atmospheric temperature is approximately 300° K. Where is that temperature indicated on the Celsius scale? On the Fahrenheit scale?

3. At 200 km. above the earth, the atmospheric temperature is approximately 700° K. Convert the Kelvin scale temperature to the Celsius scale. To the Fahrenheit scale.

4. If the temperature of the atmosphere at 500 km. is approximately 1000° on the Kelvin scale, what is it according to the Celsius scale? Convert the Celsius scale reading to the Fahrenheit scale.

Change the following Celsius scale readings to °Fahrenheit.

	Celsius	Fahrenheit
5.	58°	136.4°
6.	25	
7.	10	
8.	5	
9.	35	

Change the following Fahrenheit scale readings to °Celsius.

	Fahrenheit	Celsius
10.	58°	14.4°
11.	77	
12.	86	
13.	60	
14.	104	

Answers

1. -58°C; -72.4°F
2. 27°C; 80.6°C
3. 427°C; 800.6°F
4. 727°C; 1340.6°F
6. 77
7. 50
8. 41
9. 95
11. 25
12. 30
13. 15.6
14. 40

THRUST

Objective

To gain facility in calculating the amount of thrust developed by a rocket engine.

Background Information

The propulsion of a rocket is explained by Newton's third law of motion which states that for every action there is a reaction equal in size and opposite in direction. The thrust or "reaction" depends partly upon the velocity or speed of the "action" and partly upon mass. The "mass" of an object refers to its bulk, not its weight.

For calculating the thrust developed in a rocket engine, the following equation could be used:

$$F = \frac{W\,v}{g} + (P_e - P_a)\,A_e$$

where F = the thrust in pounds
W = the rate of discharge of the gas or liquid jet in pounds per second
v = the velocity in feet per second
g = 32.2 feet per second per second (gravitational acceleration)
P_e = the pressure of the rocket gases at the exit of the nozzle in pounds per square inch
P_a = the pressure of the atmosphere surrounding the rocket in pounds per square inch
A_e = the area of the exit nozzle in square inches

Activities

1. A rocket gives off exhaust gas at the rate of 100 lb. per second at a pressure of 25 lb. per square inch. The gas is traveling at a velocity of 7500 feet per second. The pressure of the surrounding atmosphere is 15 lb. per square inch, and the area of the exit nozzle is 50 square inches. What is the thrust of the rocket?

2. What would be the answer to Problem 1 if the rocket gives off gas at the rate of 200 pounds per second and is traveling at a velocity of 9,000 feet per second?

3. Repeat Problem 1, but assume the pressure in the upper atmosphere to be 1.5 lb. per square inch. What is the thrust of the rocket now?

Answers
1. 23,791.9 lb. 2. 56,400.6 3. 24,466.9 lb.

SPECIFIC IMPULSE

Objective

To gain facility in determining the relative effectiveness of the performance of a rocket by calculating its specific impulse.

Background Information

Rocket performance can be determined by calculating "specific impulse"; that is the amount of propellant which must be burned per second in order to maintain a given amount of thrust. More explicitly, "specific impulse" is defined as the thrust a rocket produces when the gas is coming out of the exit nozzle at the rate of one lb. per second. Mathematically stated:

$$I_{sp} = \frac{F}{W}$$

where I_{sp} = specific impulse, in seconds
F = thrust of rocket, in pounds
W = weight of propellant used, in pounds per second

Example: What is the specific impulse of a rocket engine which has a thrust of 10,000 pounds and uses its propellant at the rate of 50 pounds per second?

By substitution in the above formula we get

$$I_{sp} = \frac{10,000}{50} = 200 \text{ seconds}$$

Normally, the higher the specific impulse the more efficient the rocket engine. With the advent of newer propulsion systems higher specific impulses can be expected.

Activities

1. What is the specific impulse of a rocket engine which has a thrust of 170,000 lb. and uses its propellant at the rate of 850 lb. per second?

2. The specific impulse of an engine is 275 seconds, and the engine has a thrust of 27,500 lb. What is the rate at which the propellant will be used?

3. What is the specific impulse of a rocket engine, like the Saturn V, which has a thrust of 7,500,000 pounds and burns 30,000 pounds of fuel per second?

Answers

1. 200 seconds 2. 100 lb./sec 3. 250 sec

Resource Materials

Books

Faget, Max, Manned Space Flight. pp. 107-11, 153-164. Space suit; aerodynamic heating of spacecraft.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 86-89, 314-315, 862-863. Specific impulse; radiation and temperature; re-entering the atmosphere.

National Aeronautics and Space Administration, "Living in Space," NASA Facts. Vol. III, No. 5, p. 11. Thermal control of space suit and spacecraft.

Shapiro, Ascher H., Shape and Flow; The Fluid Dynamics of Drag.

Sutton, Richard M., The Physics of Space. pp. 137-147. Radiation in space.

Wilson, Mitchell, Seesaws to Cosmic Rays. pp. 68-74. Caloric and kinetic theories of heat. (Easy reading)

Films

Aerodynamic Heating and Deceleration During Entry into Planetary Atmosphere (b/w, 29 min.)

Beating the Heat (c, 19 min.) Aerodynamic heating by deceleration and at supersonic speeds.

SOUND AND LIGHT

Movements of sound and light are examples of two of the many types of wave motion known in nature. Sound waves travel through gases, liquids, and solid materials while light waves travel through empty space. Either light or sound waves can be reflected or refracted in definite patterns. The compression or expansion of the wavelengths of sound and light or other electromagnetic waves can be used to determine the velocity of an object moving toward or away from the receiver.

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Doppler Shift and Stellar Velocity. . . 111
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SOUND

Objective

To be able to explain why, according to present theory, there will be no sound on the moon.

Background Information

Vibration of materials in a vacuum does not produce sound because there are no air molecules to vibrate and carry the sound to the ear. As far as we now know, there is no atmosphere upon the moon. Because of this lack of atmosphere, sound must be transmitted through some kind of electronic device such as a radio in order for it to be heard. Men on the moon will need to communicate by signaling, by direct contact, or through use of some device comparable to the walkie - talkie radios used on Earth.

Activity

Place a properly connected electric bell (door bell) or buzzer in a bell jar. Remove all the air and notice that even when the bell clapper is vibrating, no sound can be heard.

LIGHT DIFFUSION

Objective

To be able to explain why space is dark even though it is flooded with light from the sun and stars.

Background Information

To be seen light must hit the retina of the eye. In space with the lack of molecules to reflect light to the eye, no light is seen except when the light source is looked at directly. (Never look directly at the sun without heavy protective dark glasses because permanent damage can be done to the retina if intense sunlight strikes it directly.)

Activity

Demonstrate that more light is reflected when there are more particles in the air for light to hit. In a dark room, shine the light of a powerful flashlight, with a narrow beam, across the room so that a beam of the light is visible. Add chalk dust or other dust particles to the air within the beam and notice how much more visible the beam of light becomes.

FOCAL LENGTH OF SPHERICAL MIRRORS

Objective

To gain facility in calculating the focal length of spherical mirrors.

Background Information

Flat mirrors are not used as the principal mirrors in reflecting telescopes, because a flat mirror will not focus incident light rays to a point. A simple kind of curved mirror is a spherical mirror where the reflecting surface is part of a spherical object (a ball). Spherical mirrors used in astronomy are concave spherical mirrors; that is, the reflecting surface would be the inside of a ball-shaped object. To find the focal point of a concave spherical mirror you need to know only the radius of curvature of the mirror, which is the same as the radius of the imaginary sphere of which the mirror is a part. The focal point or focal length, f, of a concave spherical mirror is 1/2 the radius of curvature, R. This can be expressed symbolically as

$$f = \frac{R}{2}$$

Activities

1. Find the focal length of the following concave spherical mirrors using the given radius of curvature:

   a. 18 inches
   b. 3 feet
   c. 31 feet, 3 inches
   d. 71 feet
   e. 99 feet, 4 inches
   f. 75 centimeters
   g. 1 meter
   h. 17 meters
   i. 41 meters
   j. 38.4 meters

2. a. Which of the mirrors in Problem 1 is the most curved (having the smallest radius of curvature)?

   b. Which of the mirrors in Problem 1 is the least curved (having the longest radius of curvature)?

3. The Schmidt telescope of the Palomar Observatory has a concave spherical mirror with a radius of curvature equal to 20 feet. Find the focal length of this mirror in (a) feet and (b) meters.

Answers

1. a. 9"
   b. 1 1/2 ft
   c. 15 ft, 7 1/2"
   d. 35 1/2 ft
   e. 49 ft, 8"
   f. 37.5 cm
   g. 0.5 meter
   h. 8.5 meters
   i. 20.5 meters
   j. 19.2 meters

2. a. 18"
   b. 41 meters

3. a. 10 ft
   b. 3 meters or 3.05 meters

FOCAL LENGTH OF PARABOLIC MIRRORS

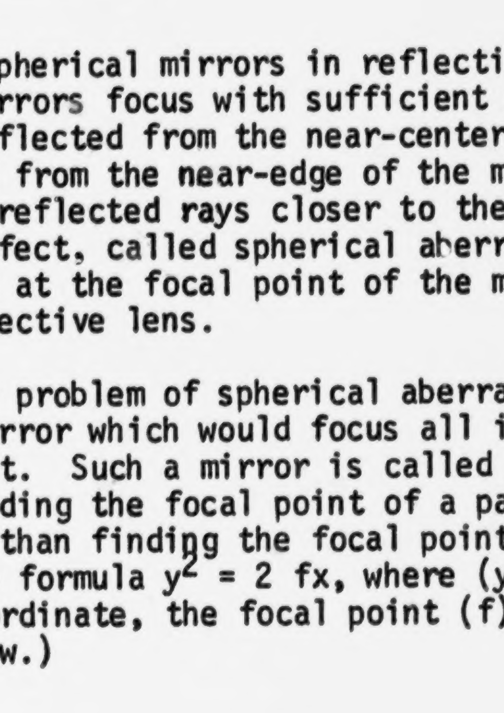
Objective

To gain facility in calculating the focal length of parabolic mirrors.

Background Information

The use of spherical mirrors in reflecting telescopes presents a problem. Spherical mirrors focus with sufficient accuracy only those light rays which are reflected from the near-center of the mirror. If a light ray is reflected from the near-edge of the mirror, it is focused behind the point where reflected rays closer to the center of the mirror are focused. This effect, called spherical aberration, destroys the sharpness of the image at the focal point of the mirror, but it may be remedied by using a corrective lens.

To solve the problem of spherical aberration, scientists designed a near-spherical mirror which would focus all incident light rays at a sharply defined point. Such a mirror is called a parabolic or paraboloidal mirror. Finding the focal point of a parabolic mirror is a bit more complicated than finding the focal point of a spherical mirror. However, by using the formula $y^2 = 2 fx$, where (y) is the y-coordinate and (x) is the x-coordinate, the focal point (f) can easily be found. (See the diagram below.)



f = 3	
y	x
0	0
±2	2/3
±3	1 1/2
±4	2 2/3
±5	4 1/6
±6	6

Activities

1. The 200-inch mirror of the Hale telescope is coated with a very thin molecular layer of aluminum which serves as the reflecting surface. Find the focal length in feet and in meters of this telescope if $x = 0.9$ feet when $y = 10.0$ ft.

2. Find the focal length of a parabolic mirror in a do-it-yourself telescope if $x = 0.5$ inch when $y = 6$ inches. What is the focal length in centimeters?

3. The Orbiting Astronomical Observatory (OAO) has a parabolic mirror 0.9 meter in diameter. Find the focal length of this mirror if $x = 1.38$ meters when $y = 4$ meters.

Answers

1. $f = 55.6$ ft. = 17 meters or 16.95 m.

2. $f = 91.4$ cm. = 36 inches

3. $f = 5.80$ meters

DOPPLER EFFECT

Objective

To gain facility in calculating velocities and wavelengths affected by the Doppler Shift.

Background Information

Wavelength and frequency can be used to determine the velocity of a sound or light source which is in motion either toward or away from the observer. When a sound or light source is in motion relative to the observer, there is a shift in the wavelength of the sound or light. This is known as the Doppler effect, or Doppler shift.

If the sound source is moving toward you, the wavelengths are crowded together and thereby shortened. This causes the sound to be pitched higher. On the other hand, if the sound source is moving away from the listener the wavelengths are stretched out and thereby lengthened. This causes a lowering of the pitch heard. This same apparent lengthening or shortening of wavelengths is present when an electromagnetic radiation source (a star) and the earth are moving toward or away from each other. The instrument which records these wavelengths is called a spectrometer. Spectrometers record information on a photograph called a spectrogram. Each wavelength present is represented by a well-defined bright or dark line, depending on what is being photographed. These spectral lines can be measured to identify elements present in the electromagnetic radiation source.

The Doppler effect can be expressed mathematically as

$$\frac{\text{change in wavelength}}{\text{normal wavelength}} = \frac{\text{velocity of source}}{\text{velocity of light}}$$

This expression may be solved for any of the four quantities contained in it. (Velocity of light is 186,000 mi/sec or 299,460 km/sec.)

Activities

1. The sun (and the solar system) is speeding toward the constellation Cygnus with a velocity of 216 kilometers per second. If a radio astronomer were to transmit a radio signal with a wavelength of 0.0035 meter toward the constellation Cygnus, what change in wavelength would be observed by a possible intelligent being on a planet revolving around a star in this constellation? (Assume that Cygnus is remaining stationary.)

2. Calculate the wavelength of the radio signal that would be received by someone on the planet mentioned in Problem 1.

3. If a satellite were launched into an orbit of high eccentricity around our sun, what would be its velocity at perihelion if the signal it transmitted had a wavelength of 7.200 millimeters and the signal received on Earth had a wavelength of 7.197 millimeters? (Note: change in wavelength = wavelength transmitted minus wavelength received.)

4. If the spectral lines of a galaxy are shifted and indicate a wavelength 1/4 of the normal wavelength, how fast is that galaxy speeding away from us?

5. If an astronomer were recording meteor trails on a spectrogram and noticed a shift in the spectral line for calcium (wavelength of 6,182 angstrom units) indicating the wavelength is shortened by 1.429 angstrom units, how fast would that meteor be moving toward Earth in (a) miles per second, and (b) kilometers per second?

6. Suppose a scientist were to point a spectrometer toward the burning gases roaring from a Saturn, Thor, or Atlas booster engine in flight. If the resulting spectrogram were to show the 6,640.900 angstrom units spectral line for oxygen to be displaced 0.054 angstrom unit, what would be the velocity of the gases being expelled from the above booster engines in (a) kilometers per second, (b) miles per second, (c) kilometers per hour, and (d) miles per hour?

Answers

1. 0.000002525 meter
2. 0.003497475 meter
3. 124.78 km/sec
4. 74,865 km/sec
5. 43 mi/sec; 69 kilometers/sec
6. 2.4 kilometers/sec; 1.5 mi./sec; 8,640 km/hr; 5,400 mi./hr

DOPPLER SHIFT AND STELLAR VELOCITY

Objective

To be able to explain how the Doppler shift in light spectra may be used to measure relative velocities of bodies in space.

Background Information

A spectroscope is used to obtain a star's light spectrum, then the position of a line in the spectrum is measured carefully. The position of this line in the star's spectrum is then compared mathematically to the position of the same line in a spectrum which is at rest relative to the earth. If the star is approaching Earth, the line shifts toward the violet end of the spectrum; if the star is moving away, the line shifts toward the red end of the spectrum.

The change toward the red end of the spectrum has been observed for several hundred galaxies and is known as the red shift. If this red shift is an indication of the Doppler phenomenon, then these galaxies are all moving away from the earth. Velocities of recession are approximately proportional to the distances from the earth; therefore, when velocity is known, approximate distance may also be calculated.

STELLAR SPECTRA

Objective

To be able to describe the way in which satellites are being used to study stellar spectra.

Background Information

The launching of the first successful OAO (Orbiting Astronomical Observatory) in December, 1968, marked the beginning of a new phase of studying the universe. For the first time, photometers and spectroscopes will collect information about the X-ray and gamma ray regions of the stellar spectra without interference by the earth's atmosphere.

Areas of investigation proposed or being conducted by the OAO program include studying (1) hot stars which radiate strongly in ultraviolet light, (2) X-ray and gamma ray radiation, (3) star evolution, (4) galaxies in ultraviolet light, (5) the center of the galaxy by collecting infrared radiation data, and (6) planetary radiations in ultraviolet and infrared.

For further information, see "Stars," in the section on Astronomy, pp. 11-16.

Resource Materials

Books

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 178-179, 829-832, 851-854. Doppler effect; the red shift; OAO

"OAO-A2, High-Accuracy Stellar Observatory," Space World, March, 1969, pp. 5-10.

Sutton, Richard M., The Physics of Space. pp. 23-24, 135-140. Measuring velocity of bodies in the universe.

Wilson, Mitchell, Seesaws to Cosmic Rays. pp. 34-50. Light; mirrors; spectrum.

Films

Dark Line to the Planets (b/w, 20 min.) Use of absorption spectroscopy to determine the atmosphere of planets.

Sound Waves and Stars: The Doppler Effect (c, 12 min.) Use of the Doppler effect to measure distances.

ELECTRICITY

The generation of electricity in space is vital to space flight because the spacecraft depends upon electricity for the operation of many of its components. Without the electronic equipment which has been developed as a part of the space program, the important task of tracking spacecraft and communicating with them could not be accomplished. In addition, numerous experiments now in progress may lead to the development of thrustors which will use electricity for spacecraft propulsion on prolonged flights.

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ELECTRIC POWER IN SPACE

Objective

To be able to describe the different ways in which electric power may be produced on space flights.

Background Information

Even though every item included aboard a spaceship is designed to use a minimum amount of power, the need for electricity is great. Either chemical, nuclear, or solar energy may be used to produce electrical energy on space flights. The type of system to be used depends upon (1) the peak power rate required, (2) the total amount of power needed for the entire mission, and (3) the length of the mission.

The simplest source of power is the primary cell which depends upon the chemical properties of the cell materials for its production of electricity. Although these storage batteries are quite efficient in producing electricity, they have the disadvantage of storing and producing a comparatively small amount of useful energy per pound of weight. The Mercury spacecraft used batteries; the Gemini and Apollo crafts obtained their power supplies for reentry and recovery periods from batteries.

A fuel cell has an advantage over a primary cell in that the chemical reactants which are expended during the production of electricity may be replaced as they are depleted. The hydrogen-oxygen fuel cells used in the Apollo service module consist of two sintered nickel electrodes separated by potassium hydroxide as the electrolyte. Oxygen is fed through one electrode, hydrogen through the other. As the reaction produces electricity, it also produces potable water, a valuable by-product.

For flights which last from a few days to less than two weeks, electrical power may be supplied by chemically-fueled turbine or internal combustion engines. Their efficiency is less than that of the primary cell, but they have a weight advantage. Of course, in addition to fuel, an oxidizer must be supplied on space flights.

Nuclear or solar powered devices for producing electricity are more suitable for flights of several weeks duration. Solar powered systems require the carrying of no fuel, and, in addition, the waste heat generated is radiated into space without any problem of providing for heat dispersion. The disadvantage of the solar powered system, of course, is that since it is dependent upon the energy it receives from the sun, the system must be able to receive sunlight either continuously or frequently enough to produce sufficient power for operation of the spacecraft equipment. So far the most feasible method for producing electric energy from solar energy is the use of solar cells which are solid state devices utilizing photovoltaic conversion. Though not efficient, only about 6 per cent of the solar energy is converted to electricity, the abundance of solar energy and the light weight of the solar cell makes this method practical. Another way of using solar energy to produce electricity is to use parabolic mirrors to concentrate the solar energy, thus converting it to heat energy which may then be changed to electricity by one of several methods.

The SNAP (Systems for Nuclear Auxiliary Power) program is investigating the possibilities of using either nuclear fission or radioactive isotopes to produce electrical power. Nuclear systems necessitate the carrying of only small amounts of fuel; however, the development of a practical nuclear powered system is complicated by the need for (1) designing an effective radiator to disperse heat, (2) the development of materials which will resist corrosion, and (3) overcoming the peculiar behavior of liquids in a weightless condition. The most practical way of using nuclear energy for the production of electricity is to convert the nuclear energy to thermal energy first. The heavy shield required for protection of the crew makes the use of nuclear reactors to produce power impractical except where large quantities of power are needed as in the case of the use of electric propulsion.

The use of radioisotope fuels as power for the production of electricity has some advantages: (1) there is no danger of runaway reaction; (2) if the decay is with alpha emissions, little shielding is needed; and (3) there is little restriction upon the size of the power unit that can be constructed. The heat output is dependent upon the isotope employed; therefore, very small compact systems can be devised. The chief disadvantage is that the fuel cannot be turned off and must be used immediately upon its manufacture to obtain maximum heat conversion.

Both nuclear reactors and the radioisotope fuels are heat producers. Some method is needed to convert the thermal energy produced into electrical energy. A steam turbine may be used. A thermionic converter in which a stream of electrons flows from a heat emitter to a cold collector is another possibility.

Activity

Construct a fuel cell.

ELECTROTHERMAL THRUSTORS

Objective

To be able to describe how electricity may be used to provide thrust for rockets.

Background Information

Electrothermal thrustors are designed to transfer to the propellant the heat produced by some electrical device. One type which is undergoing investigation is the resistance jet (resistojet) which utilizes ohmic (resistance) heating to obtain high temperatures. Several types of resistance heating sources, such as tungsten tubes, resistance coils, or resistance screens, are being tested. The propellant flows around or through the heating source to produce the high exhaust velocity. Another type of electrothermal thrustor is the electric-arc (arc-jet) which heats the propellant by means of an electric arc. The tendency for electrodes to disintegrate and the loss of energy because of the conductive quality of the heated propellant are problems to be solved. The use of electrothermal thrustors is limited by the problems of producing electrical power in space.

SPACECRAFT TRACKING AND COMMUNICATIONS

Objective

To be able to describe the electronic systems developed for communication with manned satellites, unmanned satellites and space probes.

Background Information

STADAN (Space Tracking and Data Acquisition Network), operated by NASA's Goddard Space Flight Center in Greenbelt, Maryland, is a network of 26 stations located around the world. Fourteen of these are electronic, the others are optical. Antennas at the stations, receive signals as the satellite passes overhead. The information received from the satellite is stored on magnetic tapes which are run through computers for interpretation and analysis.

Tracking of unmanned satellites is done by using either the worldwide Minitrack System, an angle measuring system using radio interferometers, to track low orbiting satellites, or the Range and Range Rate System which determines the line of direction (the range) and the radial velocity (the range rate) of spacecraft which are 500 to hundreds of thousands of miles from Earth.

Radio telemetry is used to measure and report data of all kinds. As instruments, called sensors, react, this information, in a coded electronic signal, is transmitted to Earth where it is processed by computer and converted into information for study and analysis.

NASCOM (NASA communications network) a worldwide network is also centered at Goddard Space Flight Center. This system, working through a communications processor which uses a digital computer, is so efficient that average transmission time for a message is about 5.8 seconds.

SCAMA II (Station Conferencing and Monitoring Arrangement) is the communications network, also centered at Goddard Space Flight Center, which is used for voice communication. Operated by a ground controller, this system makes it possible to communicate with an astronaut in orbit or conduct conferences with participants in different parts of the world as easily as to make a local telephone call.

The DSN (Deep Space Network) stations are located 120°-intervals of longitude apart so that one station will have a line-of-sight communication with the spacecraft at all times. This network, operated for NASA by the Jet Propulsion Laboratory at Pasadena, California, is a part of the NASCOM system, but its special assignment is to support the lunar and planetary missions.

Resource Materials

Books

Faget, Max, Manned Space Flight. pp. 117-138. Electric power generation for space flight; tracking and communications.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 158-171. Power for space flight.

Hymoff, Edward, Guidance and Control of Spacecraft. pp. 78-84. Telemetry.

National Aeronautics and Space Administration, "Solar Cells," NASA Facts S-6/3-68.

________, "Spacecraft Tracking and Communication," NASA Facts S-2/8-67.

________, "Telemetry," NASA Facts S-3/8-67

Films

Bell Solar Battery (c, 18 min.) Manufacture of solar cells, advantages of solar batteries.

Electric Propulsion (c, 24 min.)

Magnetic Force (c or b/w, 27 min.)

Power for the Moonship (b/w, 28 min.) Fuel cells and their uses on; the Apollo spacecraft.

ATOMIC AND NUCLEAR PHYSICS

In the future, nuclear energy probably will be utilized to propel rockets. Whether a nuclear reactor or a charged-particle rocket motor propels the spacecraft of the future depends upon the success of present experimental projects. Regardless of what type of motor propels the craft into space, satellites now offer possibilities for testing Einstein's general theory of relativity which was impossible to test prior to the space age.

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NUCLEAR PROPULSION

Objective

To be able to explain how nuclear reactors may be used to propel rockets.

Background Information

Chemical and nuclear rockets are similar in that both operate by expulsion of hot gas through a rocket nozzle. The nuclear reactor, placed in the rocket core, acts to heat the propellant which may, theoretically, be any liquid or gas. Usually hydrogen is chosen because of its low molecular weight. The nuclear rocket is limited in its performance potential by the high-temperature strength of the structural materials. The reactor temperature must not be allowed to reach the melting point of the structural materials which must be chosen for great high-temperature strength. Such materials include graphite, tungsten and some of its alloys, and certain refractory carbides, oxides, and sulfides. The first experimental reactor, called Kiwi, utilized graphite which, in addition to having structural strength, can act as a moderator for the nuclear material.

The thrust of a nuclear rocket can be varied (1) by altering the fission rate or (2) by varying the flow of the propellant. The latter seems to be preferable. Stopping and starting a nuclear rocket, while completely feasible, does entail the use of great care to avoid possible damage to the core material. Automatic controls which have been developed need further perfecting for complete reliability.

Of course, shielding against radiation of neutrons and gamma rays is vitally important to the safe use of these reactors. Not only are these radiations harmful to humans who may occupy the spacecraft, but they can also be harmful to some of the equipment carried aboard the craft. To avoid radiation hazards at the launch site, nuclear rockets will probably be used in the later stages of a launch vehicle.

Another use of nuclear energy as a source of heat is the use of naturally radioactive substances which can generate heat in materials which absorb the radiations. Experimental rockets which use cobalt-60 and polonium-210 as the heat source are being tested.

CHARGED-PARTICLE ROCKET MOTORS

Objective

To be able to describe the different types of charged-particle rocket motors which are being considered for use in space travel.

Background Information

Theoretically, direct acceleration of electrically-charged particles by electromagnetic fields can produce high exhaust velocities which can propel rockets. Investigation of (1) ion and colloid rockets which utilize electrostatic acceleration and (2) plasma rockets which utilize electromagnetic acceleration is being conducted.

The operation of an ion rocket involves (1) generation of ions, (2) acceleration of these ions by an electrostatic field, and (3) electrical neutralization of the ion beam which has been produced by acceleration. Two processes for ionization are being investigated: (1) contact ionization in which cesium vapor is passed through a heated tungsten grid where electrons from the cesium atoms cling or (2) electron-beam ionization in which a beam of fast electrons from an electrically heated cathode is passed through vapor of the material (usually mercury) to be ionized. Ionization of the positive ions is followed by acceleration by an electrostatic field. After passing through the accelerating grid, the ions are decelerated to some extent before they are exhausted from the rocket.

In the SERT I (Space Electric Rocket Test) during July, 1964, two ion rockets, one using mercury vapor, the other cesium vapor, were tested. The mercury vapor thrustor worked satisfactorily, but the cesium thrustor failed to start although it has worked in suborbital flight.

The colloid rocket is a modification of the ion rocket in which the material utilized is colloidal in nature. Although higher accelerating voltages are required than are required for ionic particles, the colloid rocket should be more efficient because a smaller proportion of the energy is used in the production of charged particles and the heavier particles result in a higher thrust-to-weight ratio.

The plasma (electromagnetic) rocket operation is based upon the principles of electromagnetic force in which the electrical conductor is an ionized gas, called plasma. When an electric current and a magnetic field are applied simultaneously at right angles to one another, the charged particles in the plasma are all accelerated in the same direction. The expulsion of these particles from the rocket at a high velocity produces thrust. Electromagnetic rockets are still in the early stages of development. It is not yet known whether they will prove practical for use in space flights.

SATELLITE TESTS OF RELATIVITY

Objective

To be able to describe three ways in which satellites may be used to test the general theory of relativity.

Background Information

When it becomes possible to determine with sufficient accuracy the exact orbit of a satellite, including even the smallest perturbations, it may be possible to determine the rate of advance of the line of apsides of the satellite. Although the change per revolution will be extremely small, the short orbital period means that the total advance for a year should be relatively easy to measure.

According to the relativity theory of gravitation the rotational motion of the central body should produce an advance of the pericenter of a satellite's orbit. The effects of the sun's rotation on Mercury and of the earth's rotation on the moon have been too small to determine; however, Earth satellites may be used for this purpose because the earth rotates so much faster than the sun and a satellite is much closer to the earth than the moon is.

The effect of a gravitation field upon wavelength shift might also be tested by considering the deviation in the wavelength of radio waves transmitted from a satellite to earth. The decrease in wavelength would be due to the gravitational attraction the earth exerts.

Resource Materials

Books

Gardner, Marjorie H., Chemistry in the Space Age. pp. 95-116. Nuclear rockets; electrical propulsion; solar propulsion.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 135-157, 854-859. Heat-transfer rocket engines: nuclear fission and fusion rockets; electrothermal thrustors; charged-particle rocket motors; ion rockets; colloid rockets; plasma rockets; relativity.

Hunter, Maxwell W. II, Thrust into Space. pp. 127-135, 152-158, 164-171, 193-207. Nuclear rockets; nuclear thermal and nuclear electric rockets; fusion rockets, photon rockets; relativity.

Sutton, Richard M., The Physics of Space. pp. 135-136. Relativity.

Films

Cosmic Rays (c, 27 min.) Origin and nature of charged particles.

Martian Explorer (c, 12 1/2 min.) Includes explanation of cesium ion propulsion.

Motion and Time - An Introduction to Einstein's Theory of Relativity (b/w, 11 min.)

Nuclear Propulsion in Space (c, 24 min.) Principles of the nuclear rocket.

Radio Waves (c, 27 min.) Behavior of man-made and natural radio waves.

X-ray Spectroscopy -- The Inside Story (c, 26 min.) Use of the spectroscope to study X-rays.

CHEMISTRY

Chemistry, as with other sciences, has gone into space. The chemistry of the moon, the sun, or the stars; the chemistry of rocket fuels; and the chemistry of extraterrestrial life are examples of areas where chemistry and space science interact.

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CHEMICAL ROCKETS

Objective

To be able (1) to list desirable characteristics for chemical propellants and (2) to describe liquid, solid, and hybrid propellant rocket fuels.

Background Information

Chemically-fueled rockets depend upon chemical reaction to release energy to propel the rocket. The energy released is a combination of heat energy resulting from the chemical reaction and thermal energy resulting from the increased motion of the molecules and atoms involved.

Desirable characteristics for chemical propellants include: (1) a high heating value in order to have a high specific impulse, (2) low molecular weights to avoid expending large quantities of energy to lift the reactants, (3) high heat of combustion per unit of volume to keep reactant volume small, (4) gaseous combustion products with a satisfactory rate of conversion of heat energy to kinetic energy, (5) relative stability, and (6) reasonable handling safety. Because no propellant incorporates all these characteristics, the choice of propellant necessitates some compromise. Three forms of propellants (liquid, solid, and hybrid) are being used as fuels and oxidizers.

Most common liquid oxidizers (some cryogenic) include: oxygen, fluorine, nitrogen tetroxide, nitric acid, hydrogen peroxide, and combinations of fluorine and chlorine. Liquid fuels most commonly used include hydrogen, straight chain hydro-carbons, refined kerosenes (RP), ethyl alcohol, hydrazine, ammonia, unsymmetrical dimethyl-hydrazine (UDMH), and boron compounds. The more powerful propulsion chemicals are the light nonmetals.

Liquid propellant systems may be either bipropellant or monopropellant. (Some experimentation is being done with tripropellant systems.) Common bipropellant combinations of oxidizer and fuel include: liquid oxygen and RP; nitric acid and hydrazine; nitrogen tetroxide with UDMH or one of the petroleum hydrocarbons; liquid oxygen and liquid hydrogen. Monopropellants, combining fuel and oxidizer in one, and decomposing in the presence of heat, pressure, or a catalyst, include: hydrazine, hydrogen peroxide, and the organic compound nitromethane.

Solid propellants, used to power smaller rockets and retrorockets, are of two types: double-base and composite. Nitrocellulose and a gelatinizer such as nitroglycerine are mixed in a colloidal suspension in the double-base propellants. Additives act as catalysts or inhibitors to control the rate of burning. In the composite base group, the fuel and oxidizer are mixed together mechanically with catalysts. Most common oxidizers are: ammonium nitrate, potassium perchlorate, and ammonium perchlorate.

Fuels include asphalt, rubber, or some type of plastic polymer. Solid propellants offer the following advantages over liquid propellants: ease of storage, minimum maintenance, and instant readiness.

Hybrid engines use a combination of liquid and solid propellants -- usually a liquid oxidizer and a solid fuel. Oxidizers include liquid fluroine, hydrogen peroxide, chlorine trifluoride, nitrogen tetroxide, and perchloryl fluoride. Fuels include solid hydrocarbons, aluminum, metal hydrides of beryllium, or lithium. Problems related to the inability to maintain uniformity in the gaseous products and in the burning of the propellants must be solved to increase the value of hybrid propellants.

EXTRATERRESTRIAL LIFE

Objective

To be able to describe the methods proposed for detecting extraterrestrial life.

Background Information

Theoretically, life could have evolved chemically under the conditions which were present in the early stages of the evolution of our planet Earth. The temperature, atmospheric conditions, and energy sources needed were all present. The primitive atmosphere probably contained ammonia, methane, water vapor and hydrogen, but no oxygen to cause oxidation. Lightning, ultraviolet light, or volcanic heat could have been the energy source. Simulation of these primitive conditions in the laboratory have resulted in the formation of organic compounds which possibly are the precursors of life as we know it.

The detection of extraterrestrial life is both a scientific and an engineering problem. One problem is related to the stage of evolution that may have been reached by the life on an unknown planet. Life might be at any stage from early chemical evolution, which would require one kind of detection apparatus, to the stage where life has evolved and disappeared leaving only fossil record of its existence, which would require a different method of detection. Evidence of extraterrestrial life might be collected through (1) finding evidence of growth, (2) collecting evidence of metabolic changes, or (3) identifying compounds which are evidence of life here on Earth. Devices being considered by NASA include (1) the Wolf trap and Gulliver which depend upon evidence of growth in a nutrient solution; (2) devices which depend upon gas chromatography to identify organic compounds; (3) an apparatus which uses a mass spectrometer to analyze compounds; (4) an instrument called a "Mars Microscope" which is a completely automated microscope to be used to study samples of Martian soil for evidence of organic compounds; and (5) the multivator which is a complex of instruments for making several types of tests.

Many scientists are analyzing meteorites to ascertain whether organisms or organic compounds are present in them. Conclusions are quite controversial because of the many possiblities for contamination of the meteorites as they pass through Earth's atmosphere and land. Other scientists are monitoring communication wavelengths to try to determine if there is evidence of intelligent life in space.

Life, other than that based on the carbon atom which we find here on Earth, has been postulated. The possiblity of a life form based upon the silicon atom has been suggested. Perhaps, ammonia, instead of water, could be the solvent for another life form. Sulfur, rather than oxygen, has been proposed as a possible respiratory chemical. At very high temperatures, fluorine-silicon or fluorocarbon biologies might evolve. At extremely low temperatures, liquid ammonia, liquid methane, or even liquid hydrogen might serve as a solvent for life.

Resource Materials

Books

Gardner, Marjorie H., Chemistry in the Space Age. pp. 71-94. Solid and liquid propellants.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 89-117, 720-724. Chemical rockets: liquid and solid propellants; detection of life on Mars.

Hunter, Maxwell W., II, Thrust into Space. pp. 38-51, 68-77, 115-123. Solid and liquid propellant rockets.

National Aeronautics and Space Administration, "Biosatellites," NASA Facts. Vol. II, No. 10. Biological space hazards; biosatellite experiment proposals.

________, Space Resources for Teachers - Biology. pp. 160-188. Detection of extraterrestrial life; decontamination of space probes, chemical evolution of life.

Young, Richard S., Extraterrestrial Biology. pp. 58-82. Detection of extraterrestrial life.

Films

Biochemical Origin of Terrestrial Life (b/w, 30 min.)

The Chemistry of Life (c, 18 min.)

How Did Life Begin? (c, 20 min.)

Life on Other Planets (c, 19 min.)

RESOURCE MATERIALS

Books 147

Films 153

Other Media 157

Distributors and Publishers . . . 159

BOOKS

Ahrendt, Myrl H., *The Mathematics of Space Exploration*. New York: Holt, Rinehart and Winston, Inc., 1965

Axford, W. I., "The Magnetosphere," *The Earth in Space*. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 117-125

Bennett, Clarence E., *Physics Without Mathematics*. New York: Barnes and Noble Inc., 1959

Bowhill, S. A., "The Ionized Atmosphere," *The Earth in Space*. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 108-116

Branley, Franklyn M., *Exploration of the Moon*. Garden City, N.Y.: The Natural History Press, 1964

Emme, Eugene M., *A History of Space Flight*. New York: Holt, Rinehart and Winston, Inc., 1965

Faget, Max, *Manned Space Flight*. New York: Holt, Rinehart and Winston, Inc., 1965

Friedman, Herbert, "The X-Ray Universe," *The Earth in Space*. Hugh Odishaw, (ed.). New York: Basic Books, Inc. Publishers, 1967 pp. 244-253

Gardner, Marjorie H., *Chemistry in the Space Age*. New York: Holt, Rinehart and Winston, Inc., 1965

Glasstone, Samuel, *Sourcebook on the Space Sciences*. Princeton, N.J.: D. Van Nostrand Co. Inc., 1965

Goldenstein, Richard M., "Venus," *The Earth in Space*. Hugh Odishaw, (ed.). New York: Basic Books, Inc. Publishers, 1967 pp.170-179

Haber, Heinz, *Space Science*. New York: Golden Press, 1967

Hendrickson, Walter B., Jr., *Satellites and What They Do*. New York: The Bobbs-Merrill Co., Inc., 1963

Huber, Lester F. and Paul E. Lehr, *Weather Satellites*. Waltham, Mass.: Blaisdell Publishing Company, 1967

Hunter, Maxwell W., II, *Thrust into Space*. New York: Holt, Rinehart and Winston, Inc., 1966

Hymoff, Edward, *Guidance and Control of Spacecraft*. New York: Holt Rinehart and Winston, Inc., 1966

Johnson, Francis S., "The Solar Wind in Space," *The Earth in Space*. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 33-45

Kaula, W. M., "The Earth From Space," *The Earth in Space*. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 126-135

Kay, Terence, *Target: Moon*. New York: The Bobbs-Merrill Company, Inc., 1965

Kuiper, Gerard P., "The Lunar Surface," *The Earth in Space*. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 146-156

Levitt, I. M. and Dandridge M. Cole, *Exploring the Secrets of Space*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963

Lundquist, Charles A., *The Physics and Astronomy of Space Science*. New York: McGraw-Hill Book Co., 1966

Moore, Patrick and Peter J. Cattermole, *The Crater of the Moon*. New York: W. W. Norton & Co., Inc., 1967

"NASA's Nimbus B, Advanced Meteorological Satellite," *Space World*, September, 1968. Amherst, Wisconsin: Palmer Publications pp. 5-26

National Aeronautics and Space Administration, "A-R-I-E-L; First International Satellite," *NASA Facts*, C-62. Houston: NASA

________, "Biosatellites," *NASA Facts*, Vol. II, No. 10. Houston: NASA

________, *Exploration of the Moon, Curriculum Supplement*. EPS-HISD-NASA #9500 Houston: NASA

________, "Explorer XIX; The Air Density Satellite," *NASA Facts*, Vol. II-2. Houston: NASA

________, "Explorer XXIX (The Geodetic Explorer)" *NASA Facts*, Vol. No. 4. Houston: NASA

________, *Gemini IX-A*. Fact Sheet Houston: NASA August, 1966

________, *Gemini XI Mission*. Fact Sheet 291-H Houston: NASA October, 1966

________, *Gemini XII Flight and Gemini Program Summary*. Fact Sheet 291-I Houston: NASA December, 1966

________, "How to Build Inexpensive APT Ground Stations," *Technology Utilization Pamphlet*. NASA - ST 5079. Springfield, Va.: Clearing House for Federal Science and Technical Information

National Aeronautics and Space Administration, "Interplanetary Explorer Satellites," *NASA Facts*, Vol. II, No. 1. Houston: NASA

_______, "Journey to the Moon," *NASA Facts*, NF-40/11-67. Houston: NASA

_______, "Living in Space," *NASA Facts*, Vol. III, No. 5. Houston: NASA

_______, "Lunar Orbiter," *NASA Facts*, NF-32 Vol. IV, No. 4. Houston: NASA

_______, *Lunar Photographic Missions*. EPO 5/67 Houston: NASA

_______, "Manned Space Flight: Apollo," *NASA Facts*, NF-23 Vol. IV, No. 7. Houston: NASA

_______, "Manned Space Flight: Projects Mercury and Gemini," *NASA Facts*, Vol. II, No. 8. Houston: NASA

_______, "Mariner," *NASA Facts*, D-62. Houston: NASA

_______, "Mariner IV," *NASA Facts*, Vol. II, No. 9. Houston: NASA

_______, "Mariner Spacecraft; Planetary Trailblazers," *NASA Facts*, NF-39/2-68. Houston: NASA

_______, "Mariner II Reports," *NASA Facts*, NF B-4-63. Houston: NASA

_______, *The Meteorological Satellite Program: Keeping a Weather Eye Out in Space*. Washington: NASA, 1963

_______, "Nimbus," *NASA Facts*, Vol. II, No. 7. Houston: NASA

_______, "Orbiting Geophysical Observatory," *NASA Facts*, Vol. II, No. 13. Houston: NASA

_______, "Orbiting Solar Observatory," *NASA Facts*, Vol. III, No. 7. Houston: NASA

_______, "The Pioneer Spacecraft," *NASA Facts*, NF-31/Vol. IV, No. 3. Houston: NASA

_______, *Project Gemini*. Washington, D.C.: Supt. of Documents

_______, "Project Ranger," *NASA Facts*, Vol. III, No. 2. Houston: NASA

_______, "Ranger Spacecraft, " *Educational Brief*. 080265-HISD-EB-RB #10020.1. Houston: NASA

_______, "A Report from Mariner IV," *NASA Facts*, Vol. III, No. 3. Houston: NASA

_______, "Solar Cells," *NASA Facts*, S-6/3-68. Houston: NASA

National Aeronautics and Space Administration, Space Resources for Teachers - Biology. Washington, D.C.: NASA, 1969

________, "Spacecraft Tracking and Communications," NASA Facts, S-2/8-67. Houston: NASA

________, "Surveyor," NASA Facts, NF-35 Vol. IV, No. 6. Houston: NASA

________, "Telemetry," NASA Facts, S-3/8-67. Houston: NASA

________, "TIROS," NASA Facts, Vol. II, No. 12. Houston: NASA

Naugle, John E., Unmanned Space Flight. New York: Holt, Rinehart and Winston, Inc., 1965

"OAO-A2, High-Accuracy Stellar Observatory," Space World, March, 1969 pp. 5-10

Ovenden, Michael W., Artificial Satellites. Baltimore: Penguin Books, Inc., 1960

Parker, E. N., "Sun and Earth," The Earth in Space. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 46-56

Pieper, George F., "Appendix IV. The Solar Wind and the Earth's Magnetosphere," NASA's Space Science and Applications Program. Homer E. Newell, (ed.). Washington, D.C.: NASA, 1967

Shapiro, Ascher H., Shape and Flow; The Fluid Dynamics of Drag. Garden City, New York: Doubleday & Company, Inc., 1961

Sutton, Richard M., The Physics of Space. New York: Holt, Rinehart and Winston, Inc., 1965

Sykes, J. B., (translator), The Other Side of the Moon. New York: Pergamon Press, 1960

Thompson, Philip D., Robert O'Brien, and the editors of Life, Weather. New York: Time Incorporated, 1965

Urey, Harold C., "The Moon," The Earth in Space. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 136-145

von Arx, W. S., "The Ocean," The Earth in Space. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 88-96

Wanless, Harold R., Aerial Stereo Photographs. Northbrook, Ill.: T. N. Hubbard Scientific Company, 1965

Widger, William K., Jr., Meteorological Satellites. New York: Holt, Rinehart and Winston, Inc., 1966

Wilson, Mitchell, Seesaws to Cosmic Rays. New York: Lothrop, Lee & Shepard Co., Inc., 1967

Wise, Donald U., "Mars," *The Earth in Space*. Hugh Odishaw, (ed.). New York: Basic Books, Inc., Publishers, 1967 pp. 159-169

Young, Richard S., *Extraterrestrial Biology*. New York: Holt, Rinehart and Winston, Inc., 1966

FILMS

Aerodynamic Heating and Deceleration During Entry into Planetary Atmosphere (b/w, 29 min.) NASA-Manned Spacecraft Center

Atmospheric Pressure (b/w, 11 min.) Encyclopaedia Britannica Films

Apollo Lunar Mission - Update (c, 17 min.) NASA-Manned Spacecraft Center

Basic Physical Science: What is Uniform Motion? (b/w, 13 min.) Indiana University, Audio-Visual Center, Circulation Department

Beating the Heat (c, 19 min.) NASA-Manned Spacecraft Center

Bell Solar Battery (c, 18 min.) Bell System Telephone

Biochemical Origin of Terrestrial Life (b/w, 30 min.) McGraw-Hill Films

Centripetal Force and Satellite Orbits (c, 11 min.) Coronet Instructional Films

The Chemistry of Life (c, 18 min.) NASA-Manned Spacecraft Center

Close-up of Mars (b/w, 30 min.) Indiana University, Audio-Visual Center, Circulation Department

The Clouds of Venus (c, 29 min.) NASA-Manned Spacecraft Center

Cosmic Rays (c, 27 min.) University of Michigan, Audio-Visual Education Center

Dark Line to the Planets (b/w, 20 min.) Cenco Educational Aids

Destination Moon (c, 20 min.) RCA

Electric Propulsion (c, 24 min.) NASA-Manned Spacecraft Center

Elliptical Orbits (b/w, 19 min.) Modern Learning Aids

Exploring the Magnetosphere and Beyond (c, 29 min.) NASA-Manned Spacecraft Center

The First Soft Step (b/w, 28 min.) NASA-Manned Spacecraft Center

Free Fall and Projectile Motion (b/w, 27 min.) Modern Learning Aids

Free Fall in Space (c, 4 min.) Film Associates of California

Gravity, Weight, and Weightlessness (c or b/w, 11 min.) Film Associates of California

How Did Life Begin? (c, 20 min.) NASA-Manned Spacecraft Center

Life On Other Planets (c, 19 min.) NASA-Manned Spacecraft Center

The Log of Mariner IV (c, 27 min.) NASA-Jet Propulsion Laboratory

Lunar Bridgehead (b/w, 29 min.) NASA-Manned Spacecraft Center

Lunar Landing - The Mission of Surveyor I (c, 15 min.) NASA-Manned Spacecraft Center

The Lunar Orbiter (c, 26 min.) NASA-Manned Spacecraft Center

Magnetic Force (c or b/w, 27 min.) McGraw-Hill Films

Martian Explorer (c, 12 1/2 min.) Boeing Company, News Bureau

Motion and Time - An Introduction to Einstein's Theory of Relativity (b/w, 11 min.) University of Southern California

Next . . . The Men (c, 19 min.) Hughes Aircraft Co.

A New Look at an Old Planet (c, 26 min.) NASA-Manned Spacecraft Center

Nuclear Propulsion in Space (c, 24 min.) NASA-Manned Spacecraft Center

One, One, Zero, Zero (c, 27 min.) General Dynamics/Corvair

Power for the Moonship (b/w, 28 min.) NASA-Manned Spacecraft Center

Project Mercury Summation (c, 29 min.) NASA-Manned Spacecraft Center

Radio Waves (c, 27 min.) University of Michigan, Audio-Visual Education Center

Ranger VIII Television Pictures of the Moon (b/w, 8 min.) NASA-Jet Propulsion Laboratory

Ranger IX Photographs of the Moon (b/w, 7 min.) NASA-Manned Spacecraft Center

Ranger 7-A Camera (b/w, 12 min.) RCA

Ranger VII Photographs of the Moon (b/w, 8 min.) NASA-Manned Spacecraft Center

Satellite Orbits (c, 20 min.) Rensselaer Polytechnic Institute

Seas of Infinity (c, 14 1/2 min.) NASA-Manned Spacecraft Center

Shoot the Moon (c, 28 min.) NASA-Manned Spacecraft Center

Sound Waves and Stars: The Doppler Effect (c, 12 min.) Film Associates of California

Space Orbits (c, 18 min.) U.S. Air Force

Streetcar in the Sky (c, 8 min.) TRW Systems

The Twelve Gemini (c, 20 min.) NASA-Manned Spacecraft Center

Universal Gravitation (c, 31 min.) Modern Learning Aids

Window on the Cosmos (b/w, 29 min.) NASA - Headquarters

X-ray Spectroscopy -- The Inside Story (c, 26 min.) NASA-Manned Spacecraft Center

OTHER MEDIA

Earth's Magnetism (Filmstrip) Life Filmstrips

Lunar Photographs (Pictures) NASA-Manned Spacecraft Center

NASA Photographs - Group E - Satellites and Space Probes (Pictures) NASA-Manned Spacecraft Center

Terrain Photos Lincoln Public Schools

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Garden City, New York 11531

Encyclopaedia Britannica Films
1150 Wilmette Avenue
Wilmette, Illinois 60091

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11014 Santa Monica Boulevard
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New York, New York 10017

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Northbrook, Illinois 60062

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Troy, New York 12181

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Chicago, Illinois 60611

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M. J. Flashbart
P.O. Box 34368
Houston, Texas 77034

D. Van Nostrand Co., Inc.
Princeton, New Jersey 08540

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Audio-Visual Education Center
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Ann Arbor, Michigan 48104

University of Southern California
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University Park
Los Angeles, California 90007